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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

SAMUEL LEWIS PENFIELD.

In the recent death of Samuel Lewis Penfield, the mineralogist, science in America has lost one of its best representatives, his chosen field of work its ablest exponent and investigator and the community in which he lived a man of the highest type of character. His loss is a heavy blow to his profession, to his University and to his friends. Men of his attainments come but rarely, and when they pass, the place they have made can never be exactly filled.

Attacked some three years since by a very serious malady which occasioned great anxiety, his unwearying and patient fidelity to the regimen prescribed for him and the devotion and care of his family enabled him to resist the disease, and it was hoped that his life might be prolonged for years to come. His trouble took, however, a sudden and unfavorable turn, and after a very brief illness he passed peacefully away on Aug. 12th, at the little village of South Woodstock, among the hills of eastern Connecticut, where he was spending the summer.

Penfield was born Jan. 16th, 1856, in the town of Catskill on the Hudson River, where his father, George H. Penfield, who was engaged for many years in a mercantile and shipping business, was a prominent, useful and highly esteemed citizen. His mother, whose maiden name was Ann A. Cheeseman, was of Connecticut stock; she was a notable woman in her community and family, and from both his parents Penfield had a

fine inheritance and thorough training in high principles and ideals. He was one of several children; his father's roof sheltered other members of the family, all united by strong ties of affection, and he thus grew up in an atmosphere which made him feel keenly all his life the ties of kindred and gave him a humanitarianism which strongly marked him.

His early education was received in his home and in the school at Catskill. Ideals of learning and culture were traditional in his family; some of his ancestors had been college-bred men, and it was early determined he should have a college education. To fit himself to enter Yale he attended the academy at Wilbraham, Mass., and in the autumn of 1874 he became a member of the freshman class of the Sheffield Scientific School. Like many other graduates of that institution, who have become well-known in natural science, he took the course laid out in chemistry. Languages he learned with difficulty though he retained them well, but in mathematics and natural science, and especially analytical chemistry, he excelled. He was graduated with honors in 1877, receiving the customary degree of Bachelor of Philosophy. While devoted to his studies, the social side of university life had not been neglected and he was loved and respected in his class, and made many enduring friendships.

After his graduation he became one of the assistants in the laboratory of analytical chemistry, a position held for two years and which, outside of the benefits of the training which its duties conferred, gave him excellent opportunities for continuing his chemical education. At this time Professors Brush and Edward Dana were engaged in their researches on the remarkable mineral locality at Branchville, Conn., which has become classic in the history of mineralogical science for the great number of new mineral species, chiefly phosphates, which it afforded.

The task of ascertaining the chemical composition of these minerals was confided to Penfield and his classmate and fellow assistant, now Professor H. L. Wells. The importance of the work, its great scientific interest, the new problems in analytical chemistry involved, all combined to excite the enthusiasm of the young investigators and to stimulate their powers

to the highest degree, while giving them a training of the greatest value. Penfield, who took to analytical chemistry with the keenest eagerness, no doubt in great part had his future career determined by his work during these two years and the one following, when he was transferred from the chemical to the mineralogical laboratory as assistant.

During this period he analyzed the new minerals eosphorite, triploidite, dickinsonite, fairfieldite and fillowite, and made analyses also of triphylite, childrenite, amblygonite, cymatolite, spodumene, etc. Up to this time his work, though dealing largely with minerals, had been entirely of a chemical nature and it is certain that he expected to make chemistry the subject of his life work, for in the years 1880–1881 he went to Germany to obtain advanced instruction in the organic side of this science. He spent two semesters in the laboratory of Prof. Rudolph Fittig at Strassburg and a part of the work resulted in the publication with him of a joint paper on organic compounds prepared and studied. He heard some lectures under Prof. P. Groth, at that time located at Strassburg, but there can be no doubt that, had he known the work he was to do in the future, his studies would have been almost wholly under the direction of this eminent teacher and crystallographer. He never regretted, however, the time he had thus spent, for it added greatly to his general knowledge of chemistry and to his training in the solution of chemical problems.

It was at the close of this stay in Germany that the opportunity opened which finally determined Penfield's career in science. The constant growth of the Sheffield Scientific School had laid such an increasing burden of executive duties upon its director, Professor Brush, that he was no longer able to give more instruction in mineralogy in the institution than was involved in the course of lectures on the descriptive side of the subject and suggestions and advice in advanced work. The practical work in the subject in the laboratory, the determinative mineralogy, was given by his assistant, who, at that time, was the late Dr. G. W. Hawes. The authorities of the National Museum offered the latter an opportunity to develop a department of Geology, which he accepted, and Penfield was called to fill his place. He entered on his duties with

the beginning of the fall term in 1881, having the title of Instructor in Mineralogy, and from that time until his death he was actively engaged in teaching and in extended researches in this subject. Feeling the need of more advanced training in certain ways, especially in methods of optical and microscopical research, in 1884 he again went to Germany and spent the summer semester at Heidelberg under Professor Rosenbusch and with great benefit to his future work. In 1886 he assumed entire charge of the instruction in mineralogy, he was appointed an assistant professor in 1888 and in 1893 was promoted to a full professorship and became a member of the Governing Board of the Sheffield Scientific School.

That which Penfield accomplished during his life divides naturally into two parts, the results of his investigations and his work as a teacher of mineralogy. In regard to the first the bibliography appended to this notice speaks far more eloquently to those acquainted with the history of mineralogical science during the last quarter of a century than could the efforts of any pen. Yet out of this great volume of important results of work which issued from his laboratory during the twenty-five active years of his life—results which have been equalled in scope and value by but few men during a much longer working period—certain salient facts may well be mentioned to indicate his achievements. He published over 80 papers relating to Mineralogy and Crystallography, either under his own name or in collaboration with others, besides the large number which came from the assistants and students in his laboratory and which were directly due to his inspiration and oversight. Moreover this does not include a great number of notes, representing crystallographic and chemical work, scattered through the literature as published in the papers of other workers, for Penfield was ever most generous of his time and skill in helping others and he had long come to be regarded in America as an ever present aid and final source of appeal in problems relating to mineralogy by workers in the geological sciences.

The mere statement of the volume of his work would, however, mean little unless it were taken in connection with its

quality. Both in the importance of the problems treated and in the ability and technical skill with which they are handled his work is of the very highest scientific character, and the greater part of it, together with his methods and ideas, has already become classic in the history of his science. In regard to this the following facts are of interest and may be mentioned. Fourteen new mineral species were established and described by him,—sometimes in combination with others. These are: *Bixbyite*, *Canfieldite*, *Clinohedrite*, *Gerhardtite*, *Glaucochroite*, *Graftonite*, *Hamlinite*, *Hancockite*, *Leucophoenicite*, *Nasonite*, *Nesquehonite*, *Pearceite*, *Roeblingite*, *Spangolite*.

What in reality was of even greater importance was the large number of already described minerals, many of them well known and prominent species, which he studied and whose true chemical composition and mineralogical affinities he established. These include *Alurgite*, *Amblygonite*, *Argyrodite*, *Aurichalcite*, *Childrenite*, *Chondrodite*, *Clinohumite*, *Connellite*, *Cookeite*, *Ganomalite*, *Hanksite*, *Herderite*, *Howlite*, *Humite*, *Monazite*, *Ralstonite*, *Staurolite*, *Sulphohalite*, *Topaz*, *Tourmaline* and *Turquois*.

Among the more important facts which he brought out as the result of his chemical work was the discovery of germanium in silver ores from Bolivia and the determination of the correct formula and crystallization of argyrodite, the Freiberg mineral in which germanium was originally discovered. Another contribution of the highest value was his recognition that fluorine and hydroxyl are isomorphous in chemical structures, and that they play a significant function in the composition of many minerals whose correct formulas may be derived by the application of this principle. He showed also that the variations in the physical properties of certain prominent minerals were dependent upon the variations in the relative amounts of these radicals. This was shown very strikingly to be the case with topaz, and applying these ideas to the chondrodite group of minerals, whose relations until then had proved an unsolved problem, he derived their correct compositions and showed that they formed a definite series with related physical properties. He was, moreover, able to indi-

cate the probable existence of another member of the series and to predict its composition and properties, a forecast whose correctness has since been established by Sjögren in the discovery of prolectite.

The idea of the isomorphism between hydroxyl and fluorine was suggested in the first Branchville paper by Brush and Dana from Penfield's analysis of triploidite. At first it was not accepted by prominent chemists and mineralogists, but Penfield by steady work in his laboratory again and again demonstrated its validity and importance, until now it has gained general acceptance and it has become recognized that the existence of these isomorphous radicals not only explains the structure of many minerals, but that their presence is of the greatest importance in understanding the mode of formation, especially in magmatic processes.

Another contribution of the first order, in the field of chemical crystallography, was his announcement of the mass action of complicated inorganic acids in determining crystal form. Thus while the bases in combination with such acids may be of the most diverse kinds, the system of crystallization is not affected. This was brought out in his important paper with Foote on the chemical composition of tourmaline, but has since been shown to be of wide application.

As an analytical chemist Penfield must be ranked as one of the great masters of this art. He had a broad and comprehensive grasp of its principles, was very fertile in their application, suggestive in combinations and in details and joined to this a technical skill and dexterity in manipulation that was really marvelous. In consequence of this the ease and speed with which he turned out complicated analyses of remarkable accuracy have always been a source of admiration among his friends and fellow-workers. His analysis of the rare mineral connellite and derivation of its formula was performed upon less than a tenth of a gram of material. Many similar feats of his skill might be cited. He rarely took up any new analytical method that he did not suggest excellent improvements in it, and he devised new methods, many of which are now in general use; his mineralogical papers in fact are full of contributions to analytical chemistry and he published several useful papers directly upon analytical methods.

Penfield's work as a crystallographer is scarcely of less importance than that which he performed on the chemical side of mineralogy. He handled mathematical relations with ease and clearness and his work was both rapid and accurate. His perception of crystal forms and symmetry seemed almost intuitive and in practical operations he was greatly aided by the same manual dexterity that he showed in chemical manipulation; thus he made measurements on the goniometer of crystals of such a degree of minuteness, as in the case of sperrylite, that it seemed almost impossible that they could be handled.

Besides establishing the crystallization of the new minerals already mentioned, Penfield determined that of the following species: *Amarantite*, *Argyrodite*, *Bertrandite*, *Herderite*, *Lansfordite*, *Metacinnabarite*, *Penfieldite*, *Polybasite*, *Sperrylite*, *Tiemannite*, *Willemite*.

In addition to his contributions to the crystallography of minerals we also owe to Penfield the determination of the other physical properties of many species, especially the optical; a work which he first took up in Rosenbush's laboratory and afterwards accurately and skillfully carried out whenever possible upon all of the species which he investigated.

His labors as a crystallographer were not, however, confined to minerals. For a number of years he spent much time in the determination of the crystallization and optical properties of compounds prepared in the chemical laboratory of the Sheffield Scientific School. As may be seen by reference to the appended bibliography, this work was done either directly by himself or under his care and supervision by the assistants and advanced students in the laboratory whom he had trained. Among these compounds studied there may be mentioned as of special importance the large series of new double salts, particularly the double halides, prepared by his colleague Professor Wells or under his direction. During the later years of his life Penfield gave much time and thought to the perfecting of practical methods for the solution of problems in crystallography. He was led to a study of the stereographic projection as a means of expression and in 1901 published an important paper on this subject, showing how it could be used for solving problems, not only in crystallog-

raphy, but also in astronomy, geodesy, navigation, etc. He prepared also an ingenious set of instruments for use in connection with this method of projection by means of which laborious calculations could be avoided and the problems quickly and accurately solved by graphic methods. He extended these practical methods and applied them to the drawing of crystals, devising special plates of axes to be used in connection with his instruments by which the solving of the form of a crystal and the drawing of its figure could be easily and rapidly carried out. These methods have since come into very general use.

In reviewing Penfield's work in mineralogical science one is struck, not more by its quantity than by its quality and varied aspects. He was a thoroughly trained man and had a firm grasp on every phase of his subject. He had a wide and accurate knowledge of minerals and the correctness with which he often identified them at sight seemed almost like intuition. While he clearly apprehended principles and, as has been shown, produced generalizations of wide importance, the great majority of his contributions to science are not of a theoretical nature but consist of direct and positive additions to knowledge. He had a highly analytical mind, and this combined with his inventive faculty and the great manual skill with which he was gifted made him a born investigator, one of the greatest who has yet appeared in his field of science. It is safe to say that with his gifts he would have had a successful career in whichever of the physical sciences he might have entered. The thoroughness of Penfield's work, its high quality and the completeness with which he covered every side of his subject, is well illustrated in his last paper on stibiotantalite, published in the current July number of this Journal, in conjunction with his junior associate and former pupil Professor Ford.

His services to science have been worthily recognized at home and abroad: in 1893 he was made an associate Fellow of the American Academy of Arts and Sciences in Boston: in 1896 he became a Foreign Correspondent of the Geological Society of London and his university conferred on him the degree of Master of Arts: in 1900 he was elected a member of the National Academy of Sciences: in 1902 he was chosen as a Fellow of the American Association for the Advancement of Sci-

ence, a Corresponding Member of the Royal Society of Sciences at Göttingen, Germany, and member of the Scientific Society of Christiania, Norway: in 1903 he was elected Corresponding Member of the Geological Society of Stockholm and Foreign Member of the Mineralogical Society of Great Britain: in 1904 the University of Wisconsin conferred upon him the degree of Doctor of Laws. He was also a member of the Connecticut Academy of Arts and Sciences and a Fellow of the Geological Society of America.

As a teacher Penfield was a striking example of what may be accomplished by an intelligent and painstaking devotion of one's effort toward a given end. He was not naturally gifted as a teacher—as a lecturer and speaker—as some men are. Of an extremely modest, quiet and retiring disposition and somewhat reserved except among his intimate friends, he always found it difficult, and naturally disliked, to express himself in public. Thus at the outset the management and instruction of students in numbers was for him not an easy matter. But he so entirely overcame this and perfected to so great a degree his methods of teaching, that the many students who came under his instruction regarded him as one of the best teachers in the University. In laboratory work, where the contact with the student is personal, he always had great success from the beginning of his career, because, in his kindliness of disposition, great patience and persistency, and in his interest in the student and his work, he had natural aptitudes which specially fitted him for this kind of instruction, and he took morever distinct pleasure in it. He always insisted upon great thoroughness and completeness in allotted work, and the mental discipline and training in method which students received under him were not less valuable than the knowledge of mineralogy which they acquired.

With those who came under him for advanced instruction he was particularly fortunate. The untiring care and oversight which he gave to their work and the thoroughness and accuracy upon which he insisted gave almost invariably successful results, and thus, especially in research, he communicated his own energy and enthusiasm to his pupils and stimulated their interest. This is clearly shown in the large number of important pieces

of work executed by him in conjunction with his students or by them under his direction. The writer, who was greatly aided by Penfield's instruction at the beginning of his own scientific work in mineralogy, can abundantly testify to his generous helpfulness and sympathetic interest in others and their work.

Penfield gave unlimited pains and thought to perfecting his material equipment for teaching and to this much of his success was due. In his laboratory he had many carefully chosen collections of models, of crystals and of minerals, each designed for particular purposes, and the arrangement of these and of the apparatus was carried out with a system and a completeness for uses of instruction that always excited the admiration of those qualified to judge of their character. In the same way with great skill and ingenuity he constructed models and apparatus for use in teaching crystallography and the optical properties of minerals to his classes and advanced students. Nor should there be forgotten in this connection the care and labor he expended in preparing the new edition of Brush's Manual of Determinative Mineralogy, the additions to which, dictated by his experience in teaching, are of the greatest value to students.

It was in fact a question which Penfield ever had upon his mind—how he could improve his methods and equipment for instruction, and as a result they attained to so high a degree of completeness and practice that many teachers of mineralogy who were not his pupils found a visit to his laboratories a source of help and inspiration.

It is a matter of satisfaction to his friends that, after the first attack of illness, his life was spared long enough for him to realize his cherished ambition in the completing of the new laboratories he had planned in Kirtland Hall and in the arrangement and perfecting of their equipment. In his new quarters he passed, in spite of illness, two very happy years of busy work, with his students and in investigations.

Penfield's activities were not confined to his laboratory. In the middle eighties he spent two summers as assistant in geological work to Professor Iddings in the survey of the Yellowstone Park, and later a number of summers were spent by him in northern New York, in North Carolina and Colo-

rado, collecting minerals and studying their modes of occurrence and field relations. The inspiration to a number of important pieces of work was given by these experiences. He also spent two summers in Europe, in 1894 and again in 1897, visiting other workers in his science and seeing collections and well known mineral localities. In these travels he was everywhere cordially received and made a large number of friends.

For many years Penfield, with several of his colleagues, one of whom was the late Prof. C. E. Beecher, lived in apartments in the top of one of the buildings of the Sheffield School. In this little coterie of young scientists were knitted enduring bonds of intimacy and friendship which had the most happy effect upon his life and work and in it he both gave and received.

As previously remarked, Penfield was distinguished by a broad humanitarianism, by a warm heart and ready sympathy which responded quickly to every call. He was always interested in charitable work and for many years was a weekly visitor to the children's ward in the City Hospital, where he cheered and helped the little patients.

In January 1897 he married Miss Grace Chapman of Albany, N. Y., who survives him. His great happiness in his married life and in the home circle he drew around him and in its generous hospitality was evident and a matter of sincere pleasure to all his friends.

The dominant notes of Penfield's character as a man were his benevolence, his simplicity, earnestness and downright honesty and sincerity in word and deed. These traits, together with a certain sweetness of disposition and a wonderful patience, never more strikingly shown than during his illness, greatly endeared him to his friends. To know him well was to love him.

Great as is the loss, that a man of Penfield's type should be cut off in the midst of his active career, and sincere and deep as our sorrow must be thereat, there is a satisfaction, which helps somewhat to console, in the thought that all there is to such a man can never die. The work that he achieved still remains, and better yet, the influence and memory of the high

principles he inculcated, not only in science but in daily life, as a man and a citizen, still mould the thoughts and feelings of his friends and students. His science is better today, not only by what he did, but still more by the influence he exerted and the high ideal of character he left behind him. This is a precious heritage which can never be lost.

The portrait accompanying this notice has been reproduced from a photograph taken some four years ago.

L. V. Pirsson.

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ART. XXXIV.—*The Conductivity of Air in an Intense Electric Field and the Siemens Ozone Generator;* by ARTHUR W. EWELL.

IN connection with a study of the electrical production of ozone, the writer desired information regarding the electrical conductivity of air, self-ionized in a strong electric field. Since little qualitative and no quantitative data could be found, the writer investigated the subject and obtained the results here presented.

For quantitative measurements the ionization should be uniform over a considerable cross section. Parallel electrodes of relatively large area give the most uniform field, yet at unavoidable minute projections on the electrodes the electric force will be excessive and the air will be considerably ionized before it is elsewhere. Owing to the increased conductivity of this air, the electric force increases in the remainder of the distance to the other electrode and a narrow discharge or *spark* occurs before the potential is sufficient to uniformly ionize the air.

If an alternating electromotive force is employed a plate of dielectric such as glass may be interposed in the air and any current in the air will be transmitted through the glass as a displacement current. There will still be excessive ionization in the immediate vicinity of any minute projections on the electrodes, but the dielectric prevents the appreciable extension of this ionization as a spark, and when the electric force is sufficient, the entire body of air is very uniformly ionized.

The ionization current, when large, is accompanied by a loud noise and the air between the electrodes is of a very uniform purple color.

The apparatus used is illustrated in fig. 1. The electrodes A and B, of tinned copper, and the glass plate C, constitute essentially the simplest type of Siemens ozone generator.* F and F' are equal, non-inductive resistances. E is a Thomson electrostatic voltmeter. H is one of Prof. Harold B. Smith's high potential transformers with a maximum ratio of transformation of 1000 : 1 and a capacity of 100 kw. One side of the transformer was grounded and the potential of the other side was obtained from the primary voltage, read at G. From readings of the actual secondary voltage with a Braun electrometer, K, for secondary currents of various magnitudes and phases, the ratio of transformation was found to be accurately 500 : 1, the ratio for which the primary was connected.

The discharge heated air, glass, and electrodes. Since the dielectric constant of the glass increases with rise of temperature and since it was essential that the temperature of the air

*See article by the writer in Phys. Rev., p. 244, April, 1906.

should be definite, the air under investigation, between electrodes and glass, was frequently renewed, the glass was cooled whenever it became appreciably warmer than the electrodes and the electrodes were maintained at a constant temperature by ten liter water baths directly behind them. For the small polar distances employed, such electrodes were able to keep air and glass approximately at their own temperature.

Electrode B was $30^{cm} \times 30^{cm}$. Electrode A consisted of an inner portion $20^{cm} \times 20^{cm}$, soldered directly to the water tank,

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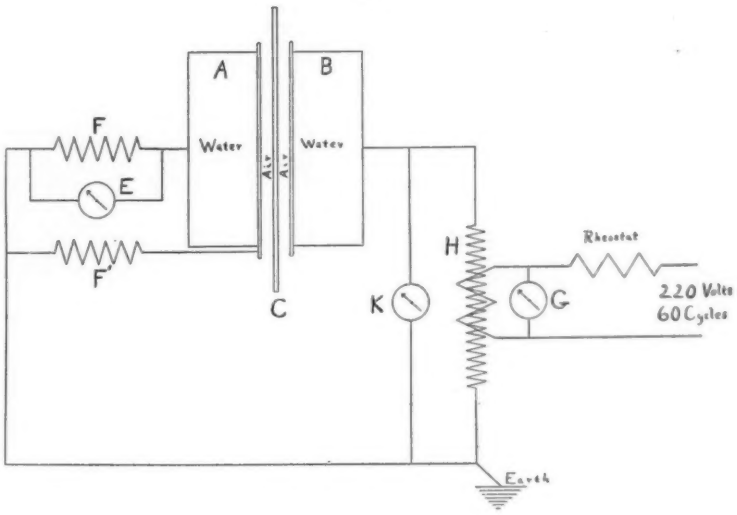
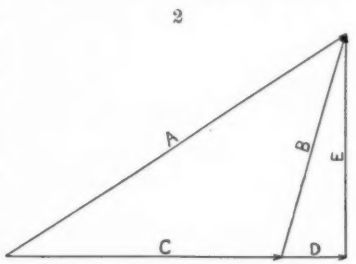


and an outer guard ring insulated from the tank, the separation from the central portion being 1^{mm} and the outer edge $30^{cm} \times 30^{cm}$. The central portion and the guard ring were accurately in the same plane. Without the guard ring there was considerable spreading of the discharge at the edges, which became particularly serious when the difference of potential was so high that the electric intensity was sufficient to ionize the air along paths bending far out from the direct line of the edges. The current through the air opposite the central portion was determined from the fall of potential across the non-inductive resistance F. The insulation of the guard ring was assured by testing with a telephone, and by measuring the current through F when F' was varied. If the insulation was perfect the current through F was practically independent of F'.

Under the alternating difference of potential between the electrodes, displacement currents traversed air and glass, and when a certain difference of potential was exceeded, depending upon the distance between the electrodes, the air was ionized and a conduction current was established in the air. The displacement currents follow well known laws and it is the current transported by the ions in the air and the electromotive force applied to the air which is of interest. The displacement current in the air is a quarter period in advance of the electromotive force and the ionization current is in phase with the electromotive force. The current in the glass will be a displacement current equal to the vectorial sum of the two currents in the air, but it is most convenient to resolve it into two parts, each in phase with the corresponding current in the air, and to resolve similarly the electromotive force applied to the glass.

In fig. 2, let A represent the total e.m.f. applied to air and glass, B the total e.m.f. applied to the glass, C that applied to the air. B is the vectorial sum of D, the e.m.f. required to maintain in the glass the equivalent of the displacement current in the air, and E the e.m.f. required for the equivalent of the ionization current in the air. A, the total applied e.m.f., is observed directly, B, the e.m.f. required to maintain the total current in the glass, can be determined with electrodes directly against the glass. Since D maintains a displacement current in the glass which requires an e.m.f. C in the air, their ratio must be the inverse ratio of the capacities of two plate condensers of equal area, one having the given thickness of air as its dielectric and the other the glass. If k is the dielectric constant of the glass, d_1 the thickness of the glass and d_2 that of the air,



$$\frac{D}{C} = \frac{d_1}{kd_2} \text{ or } D = rC \text{ where } r \text{ is a constant.} \qquad (1)$$

Moreover by geometry $C^2+2CD = A^2-B^2$

$$\therefore\ C = \frac{\sqrt{A^2-B^2}}{\sqrt{1+2r}} = \sqrt{A^2-B^2}\,(1-r+\tfrac{3}{2}r^2) \qquad (2)$$

to a sufficiently close approximation, for the e.m.f. applied to the air. The magnitude of the ionization current equals the

total current less the air displacement current, and it is the geometrical difference or the square root of the difference of the squares, since the ionizations and displacement currents differ in phase a quarter period. The displacement current obviously equals,

$$\frac{2\pi n A}{4\pi d \cdot 9 \cdot 10^{11}} C \qquad (3)$$

where n is the frequency (= 60), A the area of the electrodes, d the thickness of air, and C, as before, the e.m.f. applied to the air.

The following observations of a typical experiment will illustrate the preceding paragraphs:

July 5. Fair, Dry. Bar. = 75·2, Temp. of water = 22°·5.
Thickness of glass = ·59^{cm}, of air = ·43^{cm}.*
Primary e.m.f. = 58·6† ∴ e.m.f. applied to electrodes(= A) = 29300.†
Non-inductive resistance = 40000. Electrostatic voltmeter = 187† ∴ Total current = 4·67 milliamperes†.

From the curve of the observations of May 1 (see below) an e.m.f. of 23300 (= B) was required to maintain a current of 4·67 milliamperes in the glass. The effective area of the central portion was 404$^{cm^2}$,‡ and using the above values of the thickness and the frequency, k comes out 8·4, in electrostatic units, and r = ·16. By formula (2) the e.m.f. applied to the air = 15900 and correcting as described above for the displacement current, the ionization current in the air 4·15 milliamperes.

Observations.—Glass = Plate glass, 70^{cm} × 80^{cm}, ·59^{cm} thick.
May 1. Sultry. Bar. = 74·3, Temp. = 20°.

Electrodes of tin foil pasted on glass, areas and guard ring same as for copper electrodes described above.

E.m.f. in volts, current in milliamperes.

E.m.f.	30700	28500	26500	24200	22200	20000	18000
Current.	6·20	5·70	5·30	4 90	4·45	3·97	3·50
E.m.f.	12200	10000	7000	5000	15300		
Current.	3·00	2·45	1·90	1·38	1·00		

July 5. Dry. Bar. = 75·2, Temp. = 22°·5.
Tinned copper electrodes as described above. Thickness of air = ·43.

E.m.f.	37000	34700	32000	29300	26500	24300	21500
Current.	6·60	6·00	5·40	4·67	4·20	3·45	2·90
E.m.f.	19000	17500	16000	14000	13000	11300	40200
Current.	2·30	2·20	1·73	1·08	·77	·48	7·40

* Total thickness of air on both sides of glass. The current was not appreciably affected if the glass was not exactly midway between the electrodes.
† Effective, throughout.
‡ Maxwell, Elect. and Mag., § 228.

Conditions identical except air thickness = 1·31.

E.m.f.	36500	39300	34200	31700	29300	27000	24600
Current.	6·20	6·60	5·70	5·00	3·80	2·64	1·48
E.m.f.	22200	23000	37800	39300			
Current.	·54	·71	6·50	6·90			

July 6. Dry. Bar. = 75·9, Temp. = 20°. Air thickness = ·20^{cm}

E.m.f.	40200	38000	36200	34200	31800	29000	26300
Current.	7·80	7·30	6·70	6·30	5·60	5·00	4·35
E.m.f.	42300	39500	37500	41500	23200	21500	19300
Current.	8·20	7·60	7·00	7·90	3·70	3·30	2·75
E.m.f.	15300	12500	10500	13800	17000	8500	39500
Current.	1·88	1·26	·95	1·61	2·30	·60	7·40

Identical conditions except air thickness = 2·41.

E.m.f.	40700	40000	38200	39000	36800	35200	35700
Current.	6·90	7·00	5·70	6·40	5·00	2·75	3·55
E.m.f.	37000	38500	40500	40000	32800	31300	
Current.	5·00	5·80	6·60	6·50	1·44	·48	

These results are plotted in fig. 3 and full lines are drawn through the observations. The dotted curves show the relation between the e.m.f. applied to the air and the ionization current and are calculated, as described above, from the full curves.

As a check upon these observations, similar experiments were made with a different glass.

Glass = Window glass 70^{cm} × 90^{cm}, average thickness = ·24.

July 7. Dry. Bar. = 75·5, Temp. = 17°.

Tinfoil electrodes, pasted on glass, similar to those used with plate glass.

E.m.f.	26000	24000	22300	21200	19700	18400	15700
Current.	10·10	9·40	8·80	8·20	7·70	7·00	6·20
E.m.f.	13700	11300	9500	6300	5000	4300	
Current.	5·40	4·40	3·65	2·57	1·95	2·63	

$$k = 6·7.$$

July 9. Damp. Bar. 75·3, Temp. = 21°.

Tinned copper electrodes described above. Thickness of air = 1·66.

E.m.f.	32000	31000	29300	27500	26500	25500
Current.	10·00	8·50	6·90	5·70	3·95	2·55
E.m.f.	24800	23500	31700			
Current.	9·50	4·40	9·40			

Conditions identical except air thickness = ·30.

E.m.f.	32700	30500	29000	27000	24300	22300	19700
Current.	11·5	10·10	9·30	8·40	7·00	6·10	5·20
E.m.f.	48000	15300	12500	10500	8500		
Current.	4·07	3·10	1·96	1·19	·63		

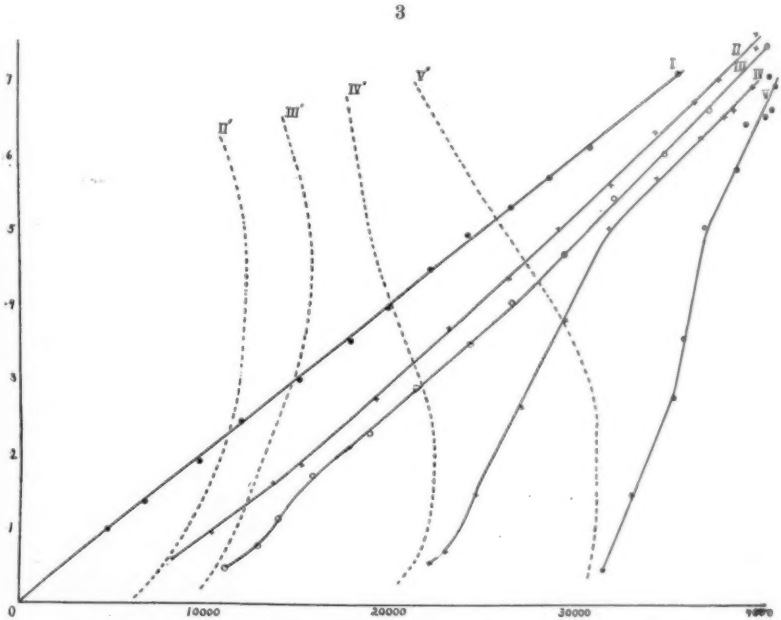


FIG. 3. Abscissæ = volts. Ordinates = milliamperes. I, Electrodes against ·59^{cm} of plate glass. II, 59^{cm} of glass + ·20^{cm} of air. III, ·59^{cm} of glass + ·43^{cm} of air. IV, ·59^{cm} of glass + 1·31^{cm} of air. V, ·59^{cm} of glass + 2·41^{cm} of air. II′, III′, IV′, and V′ are corrected curves of II, III, IV, and V respectively and give the relation between the e.m.f. applied to the air and the ionization current.

These observations are plotted in fig. 4. The corrected curves fit in well with the curves of fig. 3 for the different distances.

The lower portions of the corrected curves show the well known rapid increase of current with slight increase of potential, while in the upper portions two facts are conspicuous, first, that, *as the ionization current in the air increases the electromotive force necessary to maintain the current decreases*, and, second, that, *as the current increases, the curves for the dif-*

ferent distances approach each other. The latter result may be explained by the compensation of the reduction in electric force when the electrodes are separated, by the increased volume in which ionization occurs. The first result shows that when the current is increased beyond the values repre-

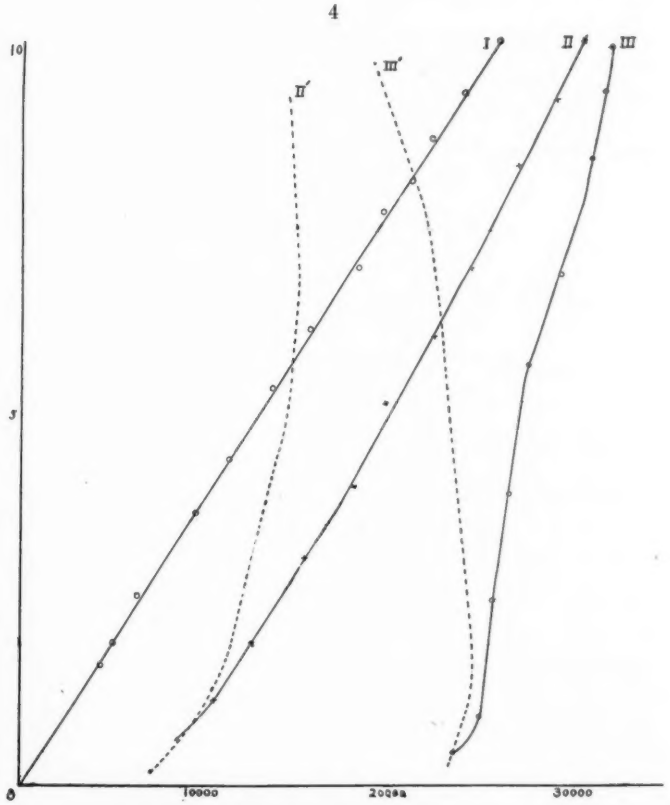


FIG. 4. Abscissæ = volts. Ordinates = milliamperes. I, Electrodes against ·24^{cm} of window glass. II, ·24^{cm} of glass + ·30^{cm} of air. III, 24^{cm} of glass and 1·66^{cm} of air. II′ and III′ are corrected curves of II and III respectively and give the relation between the e.m.f. applied to the air and the ionization current.

ented by the familiar lower portions of the curves, the air *under normal conditions* exhibits so called "*negative resistance,*" which has hitherto been demonstrated only under the

special conditions of high temperature (the arc discharge*), and low pressure.†

The following empirical formula agrees approximately with the upper portion of the corrected curves (i. e., where the current density exceeds 15 microamperes per square centimeter):

$$i = 50 - V\frac{\cdot 018}{\sqrt[3]{d}} \qquad (4)$$

where i is the current per square centimeter in microamperes and V is the electromotive force applied to the thickness, d, of air.

The effective values of the potentials at which appreciable ionization commences and the maximum electric intensity at the different distances are as follows:

Air thickness	---	·20	·43	1·31	2·41	·30	1·66
Ionization potential	---	6000	9000	19000	30000	6000	22000
Ionization intensity (max.)	---	423000	29600	21200	17000	28200	18400

The latter is given approximately by the formula:

$$F_{max} = 22{,}500\frac{1}{\sqrt[3]{d}} \qquad (5)$$

The decrease in requisite intensity for ionization with increase in distance is probably due to partial ionization.‡

In fig. 5 are plotted the *power factor* and *power absorbed* for the different distances. [From fig. 2 it is readily seen that the power factor is the sine of the angle between A, the applied e.m.f., and B, which is a quarter period in advance of the total current: $= \frac{E\,C}{A\,B}$; and the power absorbed is the product of the current, the potential applied to the electrodes, and the power factor.]

The current heats the glass but little and therefore before appreciable ionization begins the current and e.m.f. differ in phase by nearly a quarter period and the power factor is low. When ionization commences this part of the current in the air is in phase with the e.m.f. and hence the power factor increases. As the ionization current increases, however, the fraction of the total e.m.f. which is applied to the glass must greatly increase, and since in the glass, e.m.f. and current differ in phase by a quarter period, the power factor reaches a maximum and then decreases with increasing current.

* Thomson, Conduction of Elec. through Gases, § 214.

† Winkelmann, IV, 2d ed., p. 519; Townshend, Phil. Mag., March, 1905, p. 289; Toepler, Ann. der Phys., xiv, p. 757, 1905.

‡ Thomson, Conduction of Elec. through Gases, § 197.

The curves for the power absorbed show that the power absorbed does not increase proportionally with increasing distance or current and is independent of the thickness of the glass.

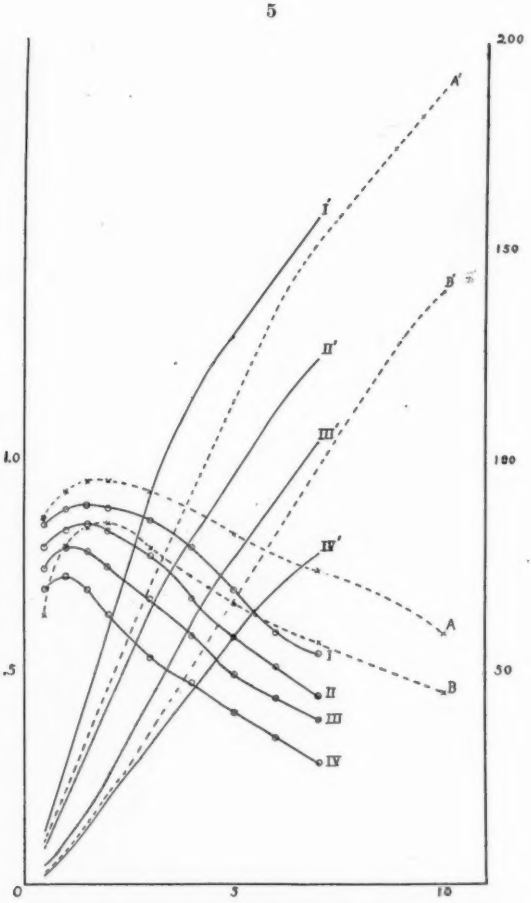


FIG. 5. Power factor and power absorbed in a Siemens ozonizer. Abscissæ = ionization current in milliamperes. Ordinates: left = power factor; right = watts. Effective area of discharge = 404$^{cm^2}$. Temp. = (approx.) 20°. I, II, III and IV give the power factors for ·59^{cm} of plate glass + ·20^{cm}, 43^{cm}, 1·31^{cm}, and 2·41^{cm} of air, respectively; A and B for ·24^{cm} of window glass + ·30^{cm} and 1·66^{cm} of air, respectively. I′, II′, III′, IV′, A′, and B′ are the corresponding curves for the power absorbed.

The complete electrical characteristics of any type of *Siemens ozonizer* may be approximately calculated from the relations given above, if the dimensions, and the dielectric constant of the dielectric for the particular frequency employed, are known. The minimum potential is obtained from equation (5). B, fig. 2, may be calculated from equation (3), adding k to the numerator, and C from equations (1) and (2) and then the ionization current per square centimeter, when large, is given by equation (4), on substituting for V

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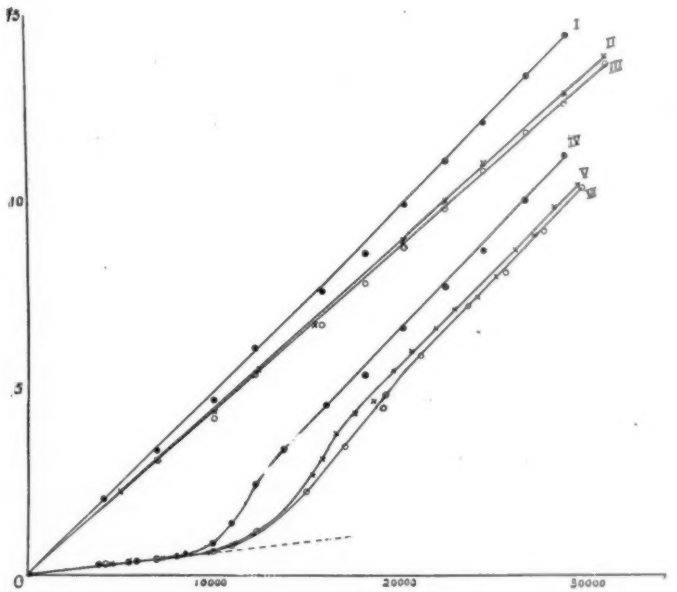


FIG. 6. Influence of Temperature. Abscissæ = volts. Ordinates = milliamperes. I, II, III, Electrodes against ·59^{cm} of plate glass. IV, V, VI, ·59^{cm} of glass + ·43^{cm} of air. Temperatures. I, 63° ; II, 20° ; III, 7° ; IV, 54° ; V, 18° ; VI, 5°. (These observations are uncorrected ; see text.)

the value found for C, and the power factor may then be calculated.

The ratio of current to electric intensity is greatest in curve V^1 of fig. 3, where 7 milliamperes are maintained by an electric intensity, F, of $\frac{21{,}000}{2{\cdot}41}$. Substituting in the equation

$$i = n\,e\,v\,F$$

10^{-19} for e; 1·55 for v, which is Chattock's value for the mean velocity of the ions in the point discharge at atmospheric pressure, under unit intensity;* and $\frac{7}{404} \cdot 10^{-3}$ for i, the current per square centimeter; n, the number of ions per cubic centimeter comes out $1.3 \cdot 10^{10}$. Taking the number of molecules per cubic centimeter as $2.4 \cdot 10^{19}$, the proportional ionization of the molecules is $2.7 \cdot 10^{-10}$.†

The effect of temperature and the displacement current before ionization begins are illustrated in fig. 6. Both electrodes were $30^{cm} \times 30^{cm}$. No guard ring was used because the insulated guard ring made it difficult to maintain a uniform temperature different from that of the room, and the area of the inner portion was too small to enable the displacement current to be measured with the apparatus at my disposal. The curves are therefore uncorrected. The temperature within this range has evidently little influence except upon the dielectric constant. The dotted line gives the calculated displacement current (equation (3)).

An alternating e.m.f. has been employed throughout for reasons explained at the beginning. The character of the e.m.f. could not, however, qualitatively affect the main results, and therefore, *for air at ordinary temperature and pressure, as the current carried through the air by ions increases, the required electromotive force slowly increases to a maximum and then decreases, and tends to become independent of the thickness of air.* Moreover, for alternating electromotive forces of approximately sine form, quantitative results have been obtained which make possible the calculation of Siemens ozonizers.

I wish to express my thanks to Prof. Harold B. Smith for the use of the high potential apparatus of the Department of Electrical Engineering.

Worcester Polytechnic Institute, September, 1906.

* Thomson, Conductivity of Elec. through Gases, p. 56.

† Compare the data given in Winkelmann, vol. IV, 2d ed., p. 561.

ART. XXXV.—*The Hydrolysis of Salts of Ammonium in the Presence of Iodides and Iodates;* by SETH E. MOODY.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxlix.]

BRUCK* has shown that when salts of ammonium are subjected to heat they are hydrolyzed and that as the acid is increased, either as a direct product of this hydrolysis, or by addition, further dissociation is inhibited. The decrease in dissociation is dependent upon the increase of the acid, and when sufficient acid is present, further hydrolysis is entirely prevented. The amount of hydrolysis is, however, small under the most favorable conditions.

It is interesting to discover how rapidly hydrolysis will proceed if the free acid is constantly removed by the presence of a mixture of potassium iodide and potassium iodate, and with this end in view a solution of ammonium sulphate, containing 5 grms. to a liter, was prepared with which to carry out subsequent experiments. The value of the solution was determined by precipitating barium sulphate, and by calculation its equivalent in iodine according to the equation

$$3H_2SO_4 + 5KI + KIO_3 = 3K_2SO_4 + 3H_2O + 6I$$

was found to be 0·4773 grm. of iodine to 25$^{cm^3}$ of the ammonium sulphate, upon the supposition that all the sulphate of ammonia can be broken up and that the full amount of sulphuric acid may be made available for reaction with the iodide-iodate mixture.

To the solution of ammonium sulphate were added potassium iodide and potassium iodate and the mixture was allowed to stand. At the ordinary temperature of the room little effect was noticed, as shown by the following results:

TABLE I.

$(NH_4)_2SO_4$. cm^3.	KI. grm.	KIO_3. cm^3.	Time in hours.	Approx. N/10 $Na_2S_2O_3$. cm^3.	I. grm.
25	1·0	20	3	0·25	0·0031
25	1·0	20	3	0·25	0·0031
25	1·0	10	19	0·35	0·0044
25	1·0	10	19	0·35	0·0044

In another series of experiments in which the solution of ammonium sulphate was boiled for three hours in an Erlenmeyer beaker before adding the iodide-iodate mixture, results were obtained which vary with the vigor of the boiling, but which show that small amounts of ammonia are volatilized, as

* Dissertation, Giessen, 1903.

shown by the subsequent slight liberation of iodine upon the addition of the iodide-iodate mixture to react with the sulphuric acid left behind. Yet the amount of hydrolysis which takes place when the ammonium sulphate is boiled with water is greater than when the ammonium sulphate and the iodide-iodate mixture are allowed to stand at the ordinary room temperature.

The following table shows the results of these experiments:

TABLE II.

$(NH_4)_2SO_4$ cm^3.	Time in hours.	KI. grm.	KIO_3. cm^3.	Approx. N/10 $Na_2S_2O_3$. cm^3.	I. grm.
25	3	1·0	10	1·25	0·0156
25	3	1·0	10	1·55	0·0193
25	3	1·0	10	1·30	0·0162
25	3	1·0	10	1·47	0·0183

If the acid produced is eliminated as fast as it is formed, the hydrolysis of the salt should proceed more rapidly. The action of the iodide-iodate mixture, which reacts with the sulphuric acid to form potassium sulphate and iodine, should bring this about; and the iodine may be removed by boiling, in the presence of a current of hydrogen, and collected for estimation. In experiments made under these conditions it was found, curiously enough, to be impossible to collect the iodine in the Drexel flask used as a receiver when charged with potassium iodide only, although it was evident that much iodine came over. It appeared, upon investigation, that ammonium iodide and ammonium iodate were formed by reaction in the receiver between the liberated iodine and the ammonia also volatilized, and to obviate the difficulty sulphuric acid was added to the contents of the receiver into which the distillate was passed. Under these conditions iodine is obtained in amount corresponding to that which should be eliminated when the ammonium sulphate is entirely hydrolyzed.

This is shown in the subjoined table:

TABLE III.

$(NH_4)_2SO_4$. cm^3.	KI. grm.	KIO_3. cm^3.	Time in hours.	H_2SO_4 (1 : 1) in the receiver. cm^3.	Approx. N/10 $Na_2S_2O_3$. cm^3.	I. grm.	Diff. grm.
25	1·0	10	3	40	38·25	0·4769	−0·0004
25	1·0	10	3	40	38·25	0·4769	−0·0004
25	1·0	10	3	40	38·30	0·4775	+0·0002
25	1·0	10	3	40	38·25	0·4769	−0·0004
25	1·0	10	3	40	38·23	0·4766	−0·0007

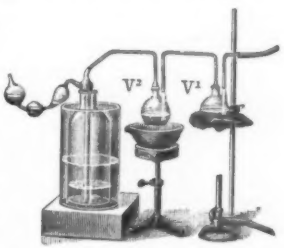
In another series of experiments, the apparatus was changed, so that the distillate passed from the first Voit flask, V^1, through a second Voit flask, V^2, containing an excess of standard acid to take up the ammonia and then into the receiver containing potassium iodide without acid.

Table IV gives results of experiments thus modified.

TABLE IV.

					Iodine equivalent of ammonia absorbed in Voit flask.			Iodine estimated in Drexel flask.		
Ammonium sulphate. cm^3.	KI. grm.	KIO_3. cm^3.	Approx. N/10. H_2SO_4. cm^3.	Time in hours.	Approx. N/10 $Na_2S_2O_3$. cm^3.	I. grm.	Diff. grm.	Approx. N/10 $Na_2S_2O_3$. cm^3.	I. grm.	Diff. grm.
25	1·0	20	50	3	38·15	0·4757	−0·0016	38·23	0·4767	−0·0006
25	1·0	20	50	3	38·20	0·4763	−0·0010	38·25	0·4769	−0·0004
25	1·0	20	50	3½	38·15	0·4757	−0·0016	38·20	0·4763	−0·0010
25	1·0	20	50	3	38·20	0·4763	−0·0010	38·27	0·4771	−0·0002
25	1·0	20	50	3½	38·17	0·4759	−0·0014	38·20	0·4763	−0·0010
25	1·0	20	50	3½	38·15	0·4757	−0·0016	38·20	0·4763	−0·0010
25	1·0	20	50	3	38·20	0·4763	−0·0010	38·25	0·4769	−0·0004

These experiments show that the sulphuric acid neutralized in the Voit flask is a measure of the ammonia while the iodine in the Drexel flask corresponds to the sulphuric acid of the ammonium sulphate.



Similar results were obtained with ammonium chloride. The exact value of a solution of 5 grms. of this salt made up to 500^{cm^3} was obtained by precipitating and weighing the silver chloride produced by silver nitrate, 25^{cm^3} of the solution containing of the salt the equivalent of 0·5922 grm. of iodine.

Portions of this solution were measured from a burette into a flask, to which was added, in each experiment, the iodide-iodate mixture and in the presence of a current of hydrogen boiled until no further color, due to iodine, remained. The distillate was passed through a trap of standard sulphuric acid, to absorb the ammonia, into the Drexel flask charged with an aqueous solution of potassium iodide to dissolve the iodine, which became known upon titration with standard sodium thiosulphate. The difference in amount of iodine which equivalent volumes of the sulphuric acid used in the trap liberated from

the iodide-iodate mixture before and after the passage of the distillate indicates the amount of ammonia volatilized in the boiling.

A table showing results of such experiments follows:

TABLE V.

					Iodine equivalent of ammonia absorbed in Voit flask.			Iodine estimated in Drexel flask.		
Ammonium chloride. cm^3.	KI. grm.	KIO_3. cm^3.	Approx. N/10. H_2SO_4. cm^3.	Time in hours.	Approx. N/10 $Na_2S_2O_3$. cm^3.	I. grm.	Diff. grm.	Approx. N/10 $Na_2S_2O_3$. cm^3.	I. grm.	Diff. grm.
25	1·0	20	50	$2\frac{3}{4}$	47·47	0·5918	−0·0004	47·45	0·5916	−0·0006
25	1·0	20	50	$2\frac{3}{4}$	47·40	0·5909	−0·0013	47·44	0·5915	−0·0007
25	1·0	20	50	$2\frac{1}{2}$	47·50	0·5922	±0·0000	47·48	0·5920	−0·0002
25	1·0	20	50	$2\frac{1}{2}$	47·45	0·5916	−0·0006	47·47	0·5918	−0·0004
25	1·0	20	50	$2\frac{1}{2}$	47·47	0·5918	−0·0004	47·48	0·5920	−0·0002

It is to be noticed that the time necessary for the hydrolysis of ammonium chloride is less than that for the sulphate.

On account of the time required, this procedure cannot be considered as having claims to be called an analytical method for determining ammonia, or the acid-ion of either of these ammonium salts, except under circumstances most extraordinary. It is here presented because the hydrolysis of ammonium salts must not be ignored in work wherein such salts are heated in solution with the iodide-iodate mixture.

Art. XXXVI.—*The Estimation of Fluorine Iodometrically;* by Albert Hileman.

[Contributions from the Kent Chemical Laboratory of Yale University—cl.]

It is obvious that the reaction by which fluosilicic acid liberates iodine from a mixture of potassium iodide and potassium iodate may be turned to account in the analysis of fluorides as well as in the determination of fluosilicic acid provided the course of action is regular.

Upon testing the action of hydrofluosilicic acid upon the iodide-iodate mixture, it was found that, while iodine is liberated freely in the cold, a complete reaction was not obtained in the course of several hours—the amount of iodine liberated indicating that an acid other than fluosilicic acid, as a unit, was acting. It appeared, however, that on boiling the mixture nearly one equivalent of iodine is liberated for every equivalent of fluorine present as fluosilicic of hydrofluoric acid. The reaction may be written

$$5KI + KIO_3 + H_2SiF_6 = 6KF + 6I + SiO_2 - H_2O$$

To the fluosilicic acid in a flask was added a neutral solution of potassium iodide and iodate in excess and the flask closed with a glass stopper fitted with a trap containing a solution of potassium iodide to retain volatilized iodine. The solution in the flask was heated to boiling, then cooled, and, together with the contents of the trap, titrated with a standard solution of thiosulphate.

In section A of Table I are given the results obtained with a solution of commercial fluosilicic acid. Titrations with sodium hydroxide and comparative iodometric determinations are given. In section B of Table I the results of similar experiments with fluosilicic acid made by the action of hydrofluoric acid on an excess of silica are given.

The indications by the iodometric method are lower than those of the alkalimetric method of titration by about 0·0008 grams, on the average. This fact would indicate that the iodine liberated does not quite correspond to the complete hydrolysis of fluosilicic acid indicated by the theoretical equation.

Likewise Table II shows the results obtained by applying the iodometric method to the silicon fluoride eliminated from calcium fluoride according to the method proposed in a previous paper.*

* This Journal, xxii, 329.

TABLE I.

H_2SiF_6	Standard $NaOH_3$	Standard $Na_2S_2O_3$	Fluorine found
		A	
	(1cm³ = 0·005137 of Fluorine)	(1cm³ = 0·002335 of Fluorine)	
cm³.	cm.	cm³.	Grams
25	10·82	----	0·0556
25	10·87	----	0·0559
25	10·83	----	0·0557
25	----	23·54	0·0549
25	----	23·52	0·0549
25	----	23·48	0·0548
25	----	23·50	0·0548
25	----	23·45	0·0548
25	----	23·48	0·0548
		B	
	(1cm³ = 0·005137F of Fluorine)	(1cm³ = 0·002441 of Fluorine)	
25	9·08	----	0·0466
25	9·05	----	0·0464
25	9·05	----	0·0464
25	----	18·78	0·0458
25	----	18·80	0·0459

Calcium fluoride was treated in the apparatus figured by the method described, the silicon fluoride was absorbed in water and after separating the mercury used in the apparatus by means of a separating funnel, the iodide-iodate mixture was added to the solution and the iodine liberated was titrated by sodium thiosulphate.

TABLE II.

CaF_2 Gram	$Na_2S_2O_3$ 1(cm³ = 002335)	Theory Fluorine	Found Fluorine	Error Fluorine
0·2500	51·35	0·1216	0·1199	0·0017
0·2300	46·75	0·1119	0·1091	0·0028
0·2300 ·NaF	47·15	0·1119	0·1100	0·0019
0·2000	38·50	0·0903	0·0899	0·0014

The average error of — 0·0019 grams is considerable greater than that of the alkalimetric method, 0·0008 grams. It appears, therefore, that, while the iodometric method of determining fluorine in fluorides may in special cases present some advantages, it does not equal in accuracy the alkalimetric method when it is properly conducted.

ART. XXXVII.—*Minerals of the Composition $MgSiO_3$; A Case of Tetramorphism;* by E. T. ALLEN, FRED EUGENE WRIGHT and J. K. CLEMENT.

PART I.—FORMATION AND PROPERTIES OF THE FOUR CRYSTAL FORMS.

The study of magnesium silicate, to which the following pages are devoted, is part of a general investigation of the pyroxene and amphibole groups, and had for its immediate object the preparation of its several crystal forms, the determination of the conditions under which these may be produced, their relative stability, and the measurement of their accessible constants. A combination of accurate data of this kind with the geologic study of the occurrence of minerals in nature constitutes the only reliable basis for the science of mineral genesis.

The materials for this synthetic work consisted of the purest quartz and magnesia which could be obtained. The quartz contained about 0·1 per cent of non-volatile impurities and the magnesia only a few hundredths of one per cent of ferric and calcium oxides. Some slight additional contamination, however, usually resulted from repeated fusion of the same material. In one of the preparations, which had been remelted many times, we found by direct analysis 0·3 per cent of ferric and aluminic oxides and practically no other impurities.

	Found.	Calculated for $MgSiO_3$.
SiO_2	59·85%	60·00%
MgO	39·77	40·00
Al_2O_3 and Fe_2O_3	·30	
	99·92	100·00

Four distinct crystal forms of magnesium metasilicate were found to exist and to be reproducible at will in the laboratory. These forms agree in their optical and other physical properties closely with the following minerals: (1) the monoclinic magnesian pyroxene*; (2) enstatite; (3) kupfferite†; (4) a monoclinic amphibole corresponding to kupfferite; our products form in fact the end members of certain solution series toward which the natural minerals approach, and sometimes almost

* Discovered by Fouqué and Lévy in certain meteorites (Bull. Soc. Min., p. 279. 1881) and by the authors in the Bishopville meteorite. We shall show later that this form differs considerably in its axial ratio $c:a$ from other pyroxenes.

† See Hintze, Mineralogie, Bd. II, p. 1196.

reach, when practically free from impurities. The conditions of formation and the properties of these four minerals will first be described; their relations to one another will then be considered in a subsequent portion of the paper.

1. *Monoclinic Pyroxene.*—This form of magnesium silicate is the product usually obtained from fusion, though small but variable quantities of enstatite and kupfferite commonly crystallize with it. Ebelmen,* who was the first to synthesize the monoclinic magnesium silicate, accomplished it by melting magnesia and silica with boric anhydride. The latter substance served as a flux and was evaporated later by long-continued heating at a high temperature. Hautefeuille† reached the same result by dissolving amorphous silica in molten magnesium chloride with partial exclusion of moisture; Stanislas Meunier‡ effected its synthesis through the action of silicon chloride and water vapor on metallic magnesium. Hautefeuille, Daubrée and other earlier observers mistook this form for enstatite. Their work was done at a time before modern microscopic methods had been developed, and their conclusions were therefore based chiefly on chemical and morphological evidence, which misled them, as was proved later by Fouqué and Lévy§ and by Vogt,‖ who examined the original preparations of Ebelmen and Hautefeuille preserved in the museum of the Collège de France.

In our own experiments we have observed the formation of the monoclinic pyroxene in several different ways: (1) from a melt of the same composition; (2) by heating the glass to a temperature above 1300°; (3) by heating any of the other crystalline forms; (4) from the action of molten magnesium chloride or tellurite on amorphous silica; (5) by recrystallizing magnesium silicate from a flux of magnesium chloride, magnesium vanadate, calcium vanadate, or tellurium dioxide.

(1.) The first method, except under conditions of slow cooling, yields crystalline aggregates, usually in radial spherulites, consisting chiefly of the monoclinic form, generally intermixed with more or less enstatite and kupfferite; but if the molten silicate crystallizes at a temperature only slightly below the melting point, an operation which can readily be carried out in the electric resistance furnace, the product is homogeneous, and consists entirely of the monoclinic form. This is the best method for preparing this substance in quantity, though the crystals are not individually well developed.

(2.) The product obtained by heating the glass to 1300° or

* Ann. Chim. Phys. (3), xxxiii, 58, 1851. † Ibid. (4), iv, 174, 1865.
‡ Comptes Rendus, xc, 349, 1880.
§ Synthèse des Minéraux et des Roches, p. 107.
‖ Mineralbildung in Schmelzmassen, p. 71. These observers also studied preparations of their own, and Vogt has described the occurrence of the same mineral in blast furnace slags.

more was similar to that from the melt, with the difference that the spherulites and their component fibers were smaller.

(3.) All other forms of magnesium silicate change to the monoclinic pyroxene by heating to temperatures from 1150° upwards, the temperature depending on the original form and the time allowed.

(4.) A repetition of Hautefeuille's work proved the correctness of his observations except as to the crystal form of his product. Magnesium chloride dissolves amorphous silica in the presence of small quantities of moisture

$$(MgCl_2 + H_2O + SiO_2 = MgSiO_3 + 2HCl)$$

but exerts little action on quartz. Instead of the chloride one may use the tellurite, an easily fusible salt which acts as readily on the silica as the chloride, has the advantage of being less susceptible to the action of water, and the disadvantage of being readily reducible to the metal and attacking the platinum crucible in which the fusion is made. The following equation represents the reaction:

$$MgTeO_3 + SiO_2 = MgSiO_3 + TeO_2.$$

The tellurous oxide is volatilized at the temperature of the experiment (700°–800°). The crystals obtained by both magnesium chloride and magnesium tellurite were generally small and not so well developed as those crystallized by method (5).

(5.) A considerable number of fluxes were found to dissolve magnesium silicate at temperatures of 800°–1000° and to precipitate it again in crystals of the monoclinic variety, a fact which has an important bearing on the question of the relative stability of the different crystal forms. It soon became evident, moreover, that certain fundamental questions connected with the pyroxene series could only be settled by the crystallographic study of the monoclinic form, so that we made a rather extensive investigation of the conditions necessary to obtain from these fluxes crystals sufficiently well developed for measurement. Among these solvents which did not prove satisfactory, we may mention calcium chloride, sodium sulphate, sodium chloride and potassium chloride. The last two gave small yields of an unpromising crystalline product which was not fully investigated. The fusible silicates of lead, sodium and potassium* all gave glasses. In point of time, we first tried fusible magnesium salts as probably best suited to dissolve the silicate without decomposing it. Of these there are the tellurite, the vanadate and the chloride.

With Magnesium Tellurite.—As stated above, the tellurite is a readily fusible salt, and though not soluble in water, it

*It was found later that a solution of magnesium silicate in a small quantity of sodium and potassium silicates yields good crystals of enstatite.

may be decomposed with hydrochloric acid, so that we expected to be able to remove the excess of reagent from the silicate without difficulty. The silicate and tellurite were therefore mixed in about equal quantities (about 5 grams of each) and heated in a covered platinum crucible by means of a resistance furnace to prevent reduction of the tellurite. At 1000°–1100° some monoclinic pyroxene was obtained, but the greater part of the product proved to be fosterite, formed by the decomposition of the tellurite and the volatilization of tellurous acid, which partly condensed on the cooler parts of the furnace. The equations:

$$MgTeO_3 + SiO_2 = TeO_2 + MgSiO_3.$$
$$2MgTeO_3 + SiO_2 = 2TeO_2 + Mg_2SiO_4.$$

represent these reactions. The crystals obtained by this method are not well formed and it is difficult to remove the tellurium completely.

The above reaction led us to believe that magnesium silicate might perhaps crystallize from molten tellurous oxide, but, though well developed monoclinic prismatic crystals were occasionally obtained, most of the silicate was apparently decomposed by this method.

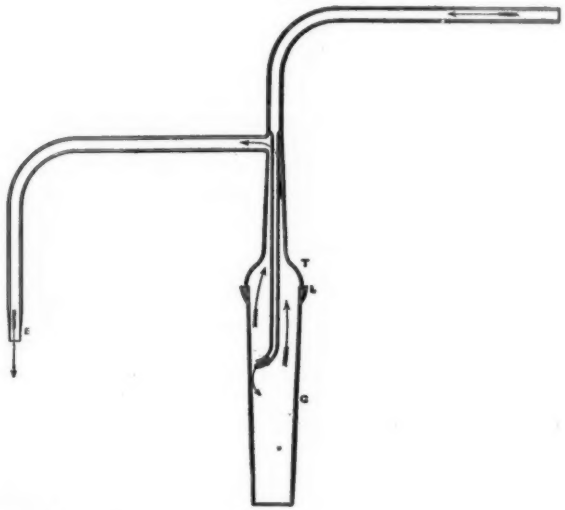
With Magnesium Vanadate.—In some earlier experiments on wollastonite carried out in this laboratory,* it was found that calcium silicate could be readily dissolved and recrystallized from molten calcium vanadate, the excess of which could be easily removed by alternate treatment with very dilute hydrochloric acid and ammonia; we therefore expected to be more successful with magnesium vanadate than with tellurite. The conditions followed in the beginning were similar to those which had worked so well with calcium silicate, but as the first results were not satisfactory, we eventually tried various proportions of silicate and vanadate at temperatures ranging from 800° to 1050°. At the lower temperature monoclinic crystals of rather poor development were obtained, but at the higher temperature a good deal of fosterite always accompanied it, and vanadic anhyride was evidently set free, as the product was colored a dark brown. Most of the vanadate and vanadic acid can be removed by cold dilute hydrochloric acid and hot concentrated ammonia, but several per cent are generally retained by the silicate.

With Calcium Vanadate.—In spite of our apprehension of double decomposition with salts containing no common ion, we found that calcium vanadate dissolved and crystallized magnesium silicate unchanged in composition and sufficiently

* Allen, White and Wright, this Journal (4), xxi, 97, 1906.

well developed for goniometric measurement. The best results were obtained by following the conditions just referred to for the formation of wollastonite.*

1



With Magnesium Chloride in a stream of Hydrochloric Acid Gas.—These experiments were carried out in the platinum crucible fig. 1, invented by Professor Gooch for the determination of water in difficultly decomposable silicates.† It consists essentially of a long crucible slightly conical in form, with a collar around the top so constructed as to leave a narrow groove between it and the cap which covers the crucible. Into this groove sodium tungstate can be melted to form an air-tight seal. The cap is so constructed as to permit the passage of a current of gas through the crucible.

Two or three grams of magnesium silicate were first put into the dry uncovered crucible. A quantity of anhydrous magnesium chloride, prepared by the decomposition of magnesium-ammonium chloride‡, was heated just before the experiment in a current of dry hydrochloric acid gas, cooled and dropped immediately into the crucible. The cover was then

* Loc. cit.

† Bull. U. S. Geol. Survey, No. 176, p. 42.

‡ It is not easy to prepare magnesium chloride in quantity free from oxide; the product of the decomposition of magnesium-ammonium chloride, as this is ordinarily carried out, requires a thorough treatment with dry hydrochloric acid gas.

sealed on without delay and the crucible connected with a generator furnishing a slow stream of well-dried hydrochloric acid gas.* In our experiments the crucible was heated over a burner to about 1000°. It was not possible to measure the temperature inside the crucible during the progress of the work, but in the empty crucible a bare thermoelement, touching the bottom, read 1050° just before the charge was inserted. This was therefore the approximate temperature in the hottest part of the crucible. In the first experiment the outlet was left unprotected against moisture. After four days the silicate was found to be converted entirely into fosterite.

In all the later experiments with magnesium chloride, the outlet tube of the crucible was well guarded by a U-tube containing sulphuric acid and a straight tube containing calcium chloride to prevent the passage of moisture into the crucible. At temperatures between 1000°–1100° (in the hottest part of the crucible) we invariably obtained some fosterite and periclase as by-products, but in the main the substance crystallized as the monoclinic pyroxene. This method gives by far the best results of any we have discovered.

Optical Constants of Fosterite.—Inasmuch as crystals which appeared to be fosterite were often obtained in the course of our work,—crystals which by optical tests alone it was found difficult to distinguish from minute crystals of enstatite, it seemed advisable to determine the crystallographic constants of these from magnesium chloride. The crystals were colorless, transparent, and about $0{\cdot}2\times0{\cdot}1\times0{\cdot}1^{mm}$ in size, short prismatic in habit, doubly terminated, and similar to natural fosterite in appearance. The cleavage, perfect after 001 and 010, was obtained by actual fracture of a crystal under the

TABLE I.

No.	Letter.	Symbol.	Miller.	Measured.		Goldschmidt.†	
				ϕ	ρ	ϕ	ρ
1	*b*	0	001	----	0° 00′	----	0° 00′
2	*a*	0∞	010	0° 00′	90 00	0° 00′	90 00
3	*n*	∞	110	64 26	90 00	65 01	90 00
4	*d*	10	101	90 00	51 37	90 00	51 32
5	*k*	02	021	0 00	49 44	0 00	49 39
6	*e*	11	111	65 51	54 19	65 01	54 15

*The platinum is often slightly attacked during the fusion. Whether this comes from the decomposition of the chloride by oxygen:

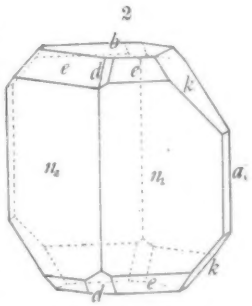
$$MgCl_2 + O + MgSiO_3 = Mg_2SiO_4 + 2Cl\ (?)$$

has not been worked out. When the magnesium coloride is mixed with sodium chloride, the platinum is very strongly attacked.

† V. Goldschmidt, Winkeltabellen, Berlin, p. 251–252, 1897.

microscope. The crystal faces were well defined, giving fair reflection signals on the goniometer. The measurements were made on a two-circle goniometer with reducing attachment, and the results were found to agree fairly well with the same constants for natural fosterite. The crystals measured were too small to permit a very accurate measurement of the angles (Table I).

The crystal represented in fig. 2 measured ·15mm in length and 0·12mm in thickness, was transparent, colorless, and well developed on all sides. The development was noticeably unsymmetrical and the quality of the different faces varied considerably. The indices of refraction were determined by Schroeder van der Kolk's method of refractive liquids in which the possible error does not exceed ±·003; a = 1·645 ± ·003, β = 1·656 ± ·003, γ = 1·668 ± ·003. Birefringence = 0·023 ± ·006. The interference colors are bright, usually of the first and second orders. The crystals extinguish parallel to the cleavage directions. The plane of the optic axes is perpendicular to the most perfect cleavage lines after 010 and to the prismatic development of the crystal and lies in the plane 001. The optic axial angle is very large with c the acute bisectrix. The crystals were decomposed by hydrochloric acid with the separation of gelatinous silica. In one preparation fosterite crystals were observed enclosing original fragments of the pyroxene which had not been fully dissolved by the solvent.



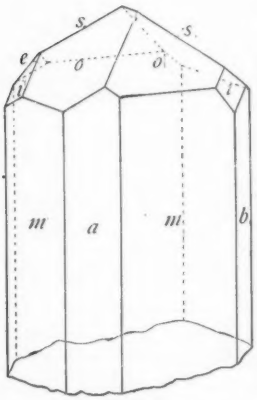
Olivine crystal from melt of $MgSiO_3$ in $MgCl_2$.

In a number of experiments with magnesium chloride we also observed the formation of periclase (MgO) in well-formed octahedra (1mm in length), isotropic and of characteristic cleavage and refractive index 1·73.

Properties of the Monoclinic Pyroxene.—Though crystals of monoclinic pyroxene were obtained from many fluxes and under different conditions, as a general rule they were extremely small and could be used only in a few favorable instances for crystallographic measurement. Crystalline aggregates of this form were also readily obtained direct from the molten silicate and then usually as large radiating spherulites, the individual fibers of which were frequently 1 to 2cm long. The crystals were measured on the two-circled goniometer with reducing attachment, were colorless, transparent, of glassy luster and varied in length from ·1 to 1mm, and in width from ·05 to ·5mm. An extremely small crystal of this substance

0·1^{mm} long and 0·04^{mm} wide, from a solution in calcium vanadate, was first measured. A single fine twinning lamella after the orthopinacoid was observed under the microscope, but could not be detected on the goniometer. The reflection signals were very faint and the recorded angles fluctuated somewhat in consequence. The largest and best developed crystals (fig. 3) were produced by heating magnesium metasilicate with magnesium chloride in a stream of dry hydrochloric acid gas. Six different crystals obtained by this method were measured and the forms: *c* (001) (?), *a* (100), *b* (010), *m* (110), *n* (120), *l* (250) (?), *k* (310), *r* (210) (?), *o* (111), *i* (121), *p* (1̄01), *s* (1̄11), *e* (1̄21), (103) (?), and (1̄03) (?) observed. Several of these forms, *c* (001) (?), *r* (210) (?), *l* (250) (?), (103), (1̄03), were noted only once, gave poor reflection signals, and are therefore uncertain. The faces in the prism zone were much better developed than the terminal forms and, although small, usually gave sharp reflection signals and concordant angles. The prismatic cleavage angle (110 : 1̄10 = 88° 08′) thus obtained has a probable error of only ± 3′. The terminal faces, on the other hand, were much smaller, less clearly defined and seriously interrupted by intergrown twinning lamellae, so that the axial ratio obtained for the vertical axis is of a lower order of certitude.

3



Mg-pyroxene.

In order to show graphically the variations in the angles observed in the different crystals, a gnomonic projection of the results from the six crystals measured is presented in figure 4. The irregularity in the position of many of the projection points is due in large measure to the indistinct reflection signals obtained. Transitional faces were observed in several zones and have been indicated in the figure by the shaded portions of the zone lines. They furnish an excellent criterion for the primary zones and nodes which dominate the development of the forms bounding the crystal.

On comparing these crystallographic measurements with the angles given for enstatite and diopside, it was found that the prism angles, and therefore the axial ratio *a* : *b* for the three minerals, were very similar, while the angles for the terminal faces differ so noticeably that they cannot be ascribed to experimental error alone. The axial ratio *a* : *b* : *c* for

4

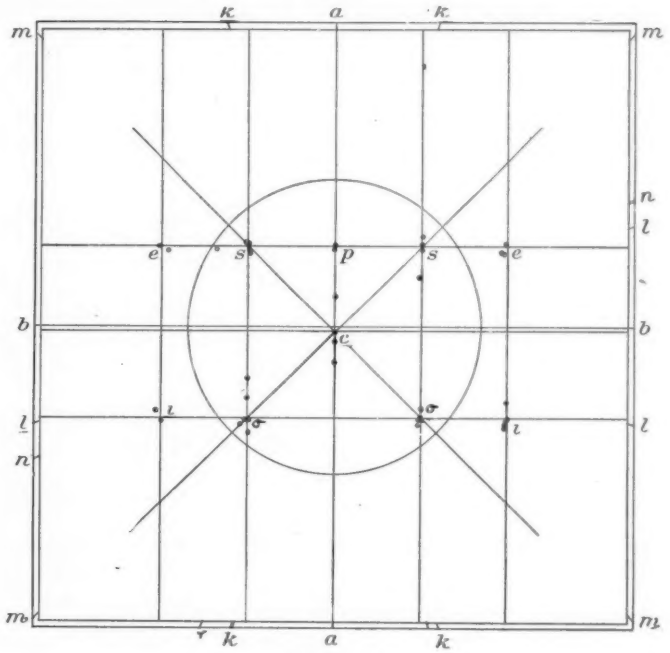


TABLE II.*

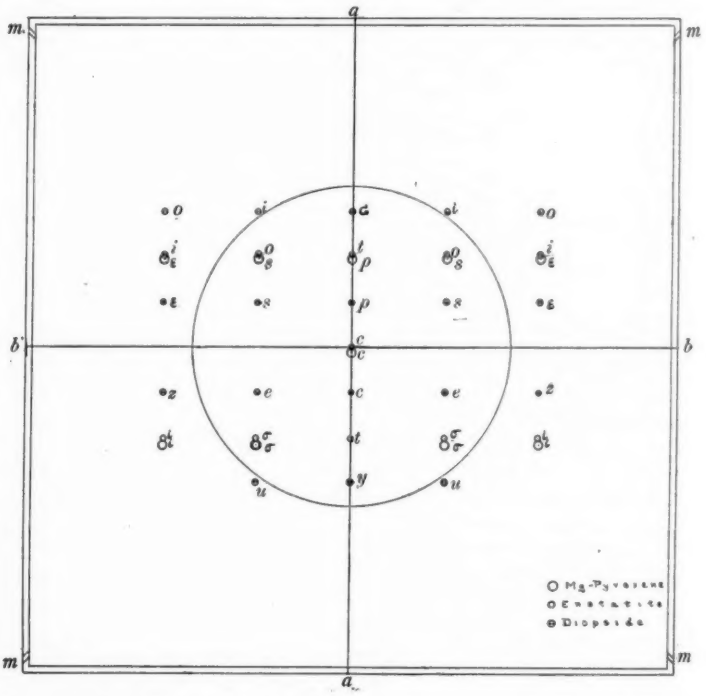
No.	Letter.	Symbol.	Miller.	ϕ	ρ
1	*c* (?)	0	001	———	2° 00′
2	*a*	∞ 0	100	90 00	90 00
3	*b*	0 ∞	010	0 00	"
4	*m*	∞	110	44 04	"
5	*n*	∞ 2	120	23 07	"
6	*l* (?)	∞ $\frac{5}{2}$	250	17 56	"
7	*k* (?)	3 ∞	310	70 44	"
8	*r*	2 ∞	210	66 54	"
9	*o*	1	111	43 29	39 58
10	*i*	12	121	24 58	52 11
11	*p*	$\bar{1}$0	$\bar{1}$01	$\bar{9}$0 00	29 09
12	*s*	$\bar{1}$1	$\bar{1}$11	$\bar{4}$6 52	40 21
13	*e*	$\bar{1}$2	$\bar{1}$21	$\bar{2}$8 30	53 10
14	(?)	$\frac{1}{3}$0	103	90 00	11 55
15	(?)	$\frac{1}{3}$0	$\bar{1}$03	90 00	12 55

*The angles given in this table are the weighted averages of the angles measured.

Mg-Pyroxene	= 1·033	: 1	: 0·77	±·01
Enstatite	= 1·0308	: 1	: 0·5885	
Diopside	= 1·0934	: 1	: 0·5894	

These relations appear even more clearly in a gnomonic projection of the most prominent forms of the three minerals (fig. 5). The character of the projection of the principal forms of the Mg-pyroxene, although distinctly monoclinic in aspect,

5



is closely related to that of the enstatite projection, and only vaguely to that of diopside. It is clear from the figure that the principal zones for diopside do not coincide with those of the Mg-pyroxene, but are located in an intermediate position. Though the symbols of the latter might be expressed very roughly in terms of diopside by choosing for the basal pinacoid of the Mg-pyroxene the possible form (102) in place of the present basal plane, thus complicating the entire set of symbols, the differences in distances between corresponding forms are even then too great to justify this change, and cast, there-

fore, grave doubt on a possible isomorphic relation between the two substances, especially when the different zonal development of the two is also taken into consideration. The investigation of this important question is still in progress.

Polysynthetic twinning after the orthopinacoid occurs almost invariably and is apparently as characteristic of this particular pyroxene as twinning according to the albite law is characteristic of the plagioclase feldspars: between crossed nicols the sections frequently bear a striking resemblance to those of plagioclase.

A peculiar type of these monoclinic crystals was observed in several of the preparations; they were developed in flat tabular form after the orthopinacoid, and in consequence of this lay invariably on this face when immersed in one of the refractive liquids. Thus the extinction was of course always parallel and might have led to erroneous conclusions in regard to the crystal system and confusion with enstatite, if special pains had not been taken to test their behavior in other positions. The crystals were accordingly imbedded in thickened Canada balsam, in which medium they could be slowly turned by moving the cover glass. The thin upturned edges then showed the polysynthetic twinning after 100, and the extinction angles characteristic of this form. In the examination of later preparations, a device for turning the crystals in any direction and in liquids of equal refractive index was constructed and proved satisfactory. The immersion method in Canada balsam, however, is less complex and usually answers equally well.

The hardness of the monoclinic pyroxene is about 6; the crystals are only slightly attacked by acids.

The refractive indices were determined by the immersion method of Schroeder van der Kolk:

$$\alpha = 1{\cdot}647 \pm {\cdot}003,\ \beta = 1{\cdot}652 \pm {\cdot}003,\ \gamma = 1{\cdot}658 \pm {\cdot}003;$$

the birefringence is not strong—about ·01. The extinction angle on the clinopinacoid—remarkably low for a pyroxene—was carefully measured on well-developed crystals obtained from a fusion of the metasilicate in magnesium chloride. These crystals were twinned polysynthetically and the extinction angle was obtained, as in the feldspars, by using the symmetrical extinction angles of adjacent lamellae. An average of 25 readings gave $c : c = 21°{\cdot}8$ (with extreme values of 19°·5 and 24°·5). Measurements in sodium light were also made with practically the same result. The dispersion of the bisectrices was found to be very slight. The plane of the optic axes lies in the clinopinacoid; the optical axial angle is very large. The optical character is positive and was ascer-

tained by observing in convergent polarized light on a section after 010 the direction in which the dark hyperbolae of the interference figure emerge from the field on revolving the stage, this direction being that of the acute bisectrix.* The result was, furthermore, confirmed on a section normal to an optic axis. An attempt was made to measure the optic axial angle on such a section by the graphic method recently described by F. Becke,† but the fine intercalated twinning lamellae affected the sharpness of the figure to such an extent that valid numerical results were out of the question. The black axial bar of the figure, however, is only slightly curved in the diagonal position and indicates a large axial angle.

The disturbing influence of the twinning lamellae was furthermore felt in some unsuccessful attempts to etch the prism faces with hydrochloric acid. The fine lamellae apparently destroyed the continuity of any larger etch figures which might otherwise have formed.

The specific gravity at 25° was determined on preparations from the melt by the method of Day and Allen :‡

Specific gravity of the Monoclinic Pyroxene, H_2O at 25° = 1.

Preparation I.	Preparation II.
3·191	3·194
3·192	3·191
Average,	3·192

Melting Point of Magnesium Metasilicate.—The melting point was determined by the Frankenheim method, using a control element, as described by Allen, White and Wright.§

The results are contained in Table III.

TABLE III.

Element E.	Element K.	
1521·3°	1521·3°	Both elements in same porcelain tube
1519·7	1522·2	Both elements in same porcelain tube
	1521·	
Mean,	1521°.	

After every experiment, elements E and K were compared with the standard element, H, which was protected from contamination and deterioration due to absorption of iridium vapor, by a tube of pure platinum. The heating coils of the furnace, which we have used heretofore, have been wound with platinum wire containing 10 per cent of iridium. It has been found that at temperatures of 1200° or more, the iridium

* Wright, F. E., this Journal (4), xvii, p. 385, 1904.
† Becke, F., Tscherm. Min. petr. Mitth., xxiv, 32–49, 1905.
‡ This Journal (4), xix, 93, 1905. § Loc. cit.

volatilizes and is absorbed by the thermoelements.* This contamination produces a drop in the electromotive force of the element which with continuous usage may result in a large aggregate error. An unglazed porcelain tube is quite permeable to the vapor. For exact measurements above 1000°, therefore, the thermoelement must be protected by an enclosing tube of pure platinum in the hot portion of the furnace, whenever a furnace coil containing iridium is used.

The maximum difference of any two determinations is 2·5°. The absolute value of the melting temperature is based on extrapolation from the copper melting point.

II. *Orthorhombic Pyroxene. Enstatite.*—So far as our knowledge goes, pure enstatite, free from other polymorphic forms, has never been prepared. Ebelmen and Hautefeuille obtained some true enstatite which was afterwards proved to be mixed with the monoclinic variety. The crystals of Meunier,† who believed that he had synthetized enstatite, were shown by Fouqué and Lévy to be monoclinic. Daubrée's product,‡ which was obtained by melting portions of meteorites, was, according to his own statement, too opaque for optical examination, so that he could not say whether his crystals were orthorhombic or monoclinic.

The same experimenter also melted olivine with 15 per cent silica, and obtained a crystalline cake, the interior of which consisted of a fibrous mass which was unattacked by acids, and "which had the properties of enstatite."§ Not only is no proof of the orthorhombic nature of these fibers offered, but we know from our own experiments that Daubrée's conditions must have yielded a product which consisted in the main of the monoclinic form. Fouqué and Lévy, in the effort to reproduce meteorites by artificial means, succeeded in crystallizing enstatite intermixed with a small amount of monoclinic pyroxene in the following way: 12 grams silica, 3 grams magnesia, and 5 to 5·5 grams ferric oxide, were melted and rapidly cooled. The cake showed arborescent crystals which by prolonged reheating at a temperature a little above the melting point of copper, developed into larger needles showing parallel extinction.

As previously stated, we also obtained enstatite in small but variable quantities from melts of magnesium silicate, except when it was slowly cooled. The crystals of enstatite thus formed were intercalated between the fibers of monoclinic pyroxene and could only be distinguished from the latter

*W. P. White, "The Constancy of Platinum Thermoelements and Other Thermoelement Problems," Phys. Rev., vol. xxii, p. 372, 1906.

† Synthèse des Minéraux et des Roches, pp. 109, 111.

‡ Compt. Rendus, lxii, 202, 1866. § Ibid., lxii, 374, 1866.

by the aid of the microscope. The two forms resemble each other so closely in habit and optical properties that one must rely chiefly on the extinction angle to distinguish between them. In the prism zone enstatite shows parallel extinction on all planes, while the monoclinic variety extinguishes parallel only on the orthopinacoid. Inasmuch as crystals of the latter frequently show pronounced development after the orthopinacoid, their monoclinic nature can only be recognized by immersing the crystals in a viscous liquid such as Canada balsam and rolling them, log-like, and observing the extinction in the different positions.

We have succeeded in preparing enstatite which contains only slight traces of impurities by a method similar to that used in this laboratory for the preparation of pure wollastonite,* and which, as may be noted, bears considerable resemblance to the method of Fouqué and Lévy. It consists simply in crystallizing a glass of the same composition by heating it to a temperature below 1100°. The practical details of preparing this glass, however, involve considerable difficulty owing to the readiness and rapidity with which crystallization proceeds in this silicate. Not more than 10 grams of it should be used for a single charge, the temperature of the platinum containing vessel should be raised well above the melting point of the silicate, and the fusion should be instantly chilled by plunging it into cold water. Care should also be taken that the temperature is sufficiently high to melt the silicate (m. p. 1521°) and yet not high enough to melt the platinum crucible (1720°). In our earlier experiments, crucibles were ruined so frequently by partial melting that we were compelled to make some rough temperature measurements by inserting a thermoelement under the hood of the Fletcher furnace. Though the temperatures thus observed were not those of the crucible, they indicated the latter approximately, and when the readings ranged from 1500° to 1550°, the results were fairly satisfactory.

Even under these conditions, the most favorable we have found, the glass is rarely obtained entirely free from crystalline material. After the glass had been mechanically separated from the latter, small samples were crystallized at various known temperatures and the products examined microscopically.

To insure the crystallization of a glass as nearly as possible at a given temperature, the following method was used. An empty platinum crucible was placed in an electric resistance furnace, through the cover of which passed a thermoelement, reaching nearly to the bottom of the crucible, together with

* This Journal (4), xxi, 89, 1906.

an unglazed porcelain tube of about 1^{cm} inside diameter, the lower end of which was directly over the uncovered platinum crucible. The upper end of this tube was covered by a porcelain lid. (An arrangement similar to fig. 10.) The temperature of the furnace having been raised to the desired temperature, the glass, in small fragments, is then dropped through the porcelain tube into the crucible. Only small fragments can be used, for the initial temperature of the crucible is materially lowered by the introduction of any considerable mass of the cold substance, after which the heat of crystallization of a large mass of the glass will raise the temperature of the portion last to crystallize above that of the furnace. At 1150°–1200°, when small particles, each of a few milligrams weight, were used, no perceptible change in the temperature of the crucible was noted. Under such conditions about 20 seconds elapsed, and we estimated that the temperature of the crucible was reached, before crystallization began. The temperature of the glass particles, however, does no doubt rise above the temperature of the crucible, for they become more luminous during the process. It is interesting to watch the crystallization; it begins at the surface and proceeds inward with rise in temperature, which is especially noticeable when the particles are large; the outer portion contracts and squeezes out the still liquid interior in the form of hollow, rounded projections, which crystallize last, and at a higher temperature, for they are always of coarser grain. These grains bear a strong resemblance to a kernel of ordinary popped corn.

Table IV contains the results of the experiments on the crystallization of magnesium silicate glass at different temperatures by the process above described.

TABLE IV.

Crystallization of Magnesium Silicate Glass.

750°	No crystallization in 45 minutes.
900	Too fine-grained for identification.
990	" " " " "
1075	Nearly all enstatite; presence of monoclinic form doubtful.
1125	Enstatite, with some monoclinic form.
1175	Enstatite and monoclinic form.
1225	" " " "
1275	" " " "
1300	Monoclinic form and probably some enstatite.
1325	" " " " " "

It is plain from these figures that below 1100° the product is enstatite; while not far above that point the monoclinic form begins to appear. To prepare a nearly homogeneous aggre-

gate of enstatite crystals in quantity, therefore, it suffices to crystallize the glass somewhat below 1100°, but not below 1000°, if the preparation requires microscopic identification, for the product then formed is cryptocrystalline. The enstatite was distinguished from the monoclinic form solely by its parallel extinction in the prism zone, the refractive indices of the two forms not differing sufficiently to permit the use of that method. By cooling mixtures of magnesium silicate with 10 per cent of its weight of albite, or the same amount of sodium and potassium silicates, enstatite may be obtained in long, well-developed prisms, the index of refraction of which indicates only a small quantity of dissolved albite or other foreign matter. Some experiments in this direction are described in detail farther on p. 433.

Properties of Chemically Pure Enstatite.—Thus far, we have obtained pure enstatite only in fibrous aggregates and radial spherulites which do not admit of a precise determination of its morphologic constants. It is a remarkable fact that the direction of elongation of the fibers in the small radial spherulites is not the prism axis, but another, such that the greater ellipsoidal axis a is parallel to it instead of c.

Cleavage after 110 is well marked; its angle approximates 90° and was observed under the microscope by tilting on end the individual fibers embedded in thick Canada balsam. The extinction is parallel in the prism zone and the least ellipsoidal axis c coincides with the prism axis.

The optical properties are similar to those of the monoclinic magnesium pyroxene, differing chiefly in the parallel instead of inclined extinction, lower average refractive index and smaller optic axial angle. The refractive indices were determined by the immersion method in liquids:

$$\alpha = 1{\cdot}640 \pm {\cdot}004,\ \beta = 1{\cdot}646 \pm {\cdot}004,\ \gamma = 1{\cdot}652 \pm .004;$$

birefringence not strong, about ·01. The plane of optic axes contains the prism axis (c = c); optical character, positive. The optic axial angle was measured on a section nearly perpendicular to an optic axis by the graphical method recently described by F. Becke.* This method is based on the difference in curvature of the black hyperbola bar which passes through the optic axis, for different optic axial angles in the diagonal position. In place of the type of revolving drawing stage described by Becke, a somewhat simpler form was devised which can be clamped directly to the microscope and can be readily adjusted to suit the conditions. This method of Becke is only an approximate one and should only be used when

*Becke, F., Die Messung der optischen Axen der Hyperbola-Krümmung. Tscherm. Min. petr. Mitth. xxiv, pp. 32–49, 1905.

better methods cannot be applied—a point which was realized and emphasized by Becke in the original paper. The values for the optic axial angle in air thus obtained were much lower than those given for natural enstatite, ranging between 44° and 70°,—a fact for which no explanation has yet been found. Similar low angles were also measured on the pure enstatite from the Bishopville, S. C., meteorite, which will be discussed in a later paragraph.

The specific gravity at 25° is lower than that for the monoclinic variety:

Preparation I (not entirely free from monoclinic).	Preparation II (free from monoclinic).
3·176	3·176
3·174	3·174
Average	3·175

Intergrowth of enstatite and monoclinic pyroxene.—Both from the molten silicate and from solutions of it, though only rarely from the latter, enstatite and the monoclinic form were obtained together, sometimes in parallel intergrowth. In a product of magnesium metasilicate in molten magnesium chloride and also in a preparation of amorphous silica heated with magnesium chloride, the intergrowth of the two phases was clearly marked on a section after the clinopinacoid (fig. 6). In the figure the arrows represent the positions at which the different lamellae extinguish between crossed nicols. Lamellae 1 and 3, monoclinic, are in twinning position and extinguish at an angle $c:c = 22°$; 2 extinguishes parallel and is enstatite.

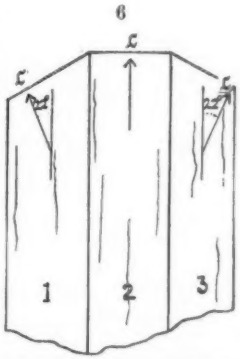


FIG. 6. Intergrowths observed on (010), Enstatite—Mg-pyroxene.

On such sections the difference in refractive indices between the two forms was very slight; the birefringence of the monoclinic lamellae appeared somewhat stronger.

Parallel intergrowths of enstatite and a monoclinic pyroxene are not uncommon in nature, and although they have been frequently described, no one, apparently, has suspected that the two forms may have the same composition.

In scanning the literature on this subject, it soon became evident that natural enstatite is rarely pure magnesium silicate, but nearly always contains some ferrous silicate. The purest enstatite is probably that of the well-known Bishopville, S. C., meteorite, specimens of which are preserved in the National

Museum. Through the kindness of Prof. C. U. Shepard, the owner of these specimens, and the courtesy of Dr. G. P. Merrill, the writers obtained ·75 gr. of this material, which, on microscopic examination, proved to contain not only enstatite but also occasional intercalated lamellae of monoclinic pyroxene identical in its optical properties with our artificial monoclinic variety. The Bishopville enstatite was analyzed by J. Lawrence Smith* and shown to be almost pure magnesium metasilicate. On this enstatite the following properties were determined: cleavage 110 good; $\gamma = 1{\cdot}658 \pm {\cdot}003$, $\beta = 1{\cdot}653 \pm {\cdot}003$, $a = 1{\cdot}650 \pm {\cdot}003$ (by Schroeder van der Kolk's method of refractive liquids); $c = \mathfrak{c}$; optic axial angle $2\text{-}V = 31°$, average of six determinations on different sections nearly normal to an optic axis by the graphical method of Becke; optical character, positive. The refractive indices of the interbanded monoclinic lamellae were very close to those of the enstatite and extinguished at an angle $c : \mathfrak{c} = 21°{\cdot}6$, an average of 10 measurements on two different sections.

Dr. G. P. Merrill has called the attention of the writers to the fact that in his experience the pyroxenes of meteorites often show extinction angles much too low for augite or diopside, and are, moreover, very frequently twinned polysynthetically after the orthopinacoid. Time has not permitted an extensive microscopic examination of natural intergrowths of enstatite and monoclinic pyroxene to test the above inference, but the conclusion seems reasonable that not only those of meteorites but those of rocks also, which are not uncommon, are likewise aggregates of two polymorphs, and do not, as generally believed, contain diopside or augite.

The Transformation of Enstatite into Monoclinic Pyroxene.—When heated to high temperatures, enstatite passes over very slowly into monoclinic pyroxene, the time required depending mainly upon the temperature, as will be readily seen from the table below.

TABLE V.

Change of Enstatite into Monoclinic Pyroxene at Different Temperatures.

Time.	Temperature.	Change.
1 day	1200°	None detected.
2 days	1250	" "
22 hours	1260 –1280°	Slight if any.
3 days	1260 –1290	Probably some change.
18 hours	1335 –1350	None detected.
17 hours	1365 –1415	Evident change.
5 hours	1440 –1460	Much change.
20 minutes	1500 max.	Apparently complete.

* This Journal (2), xxxviii, p. 225, 1864.

The above data show that in a few days time the change is first apparent between 1260° and 1290°, and that it is here extremely slow. Comparing this table with the one on p. 399, it is clear that the glass crystallizes directly to monoclinic pyroxene about 100° lower. By the use of a solvent, the same change proceeds as low as 800° and probably even lower. Calcium vanadate, or still better, magnesium chloride, under the conditions described on p. 389, yields well-shaped crystals of the monoclinic variety at 800°.

The natural enstatite of the Bishopville meteorite showed an identical behavior when heated to 1450°; the enstatite with its parallel extinction disappeared completely and was replaced by the twinned monoclinic lamellae, the latter still preserving the original prismatic direction of the enstatite and also apparently the cleavage, the size of grain of the two phases being about the same and the original outline of the enstatite fragments being still preserved after the paramorphic change. A specimen of enstatite from Webster County, North Carolina,* containing ferrous silicate also passed into the more stable monoclinic form when it was heated. Here magnetite was observed as a by-product.

III. *Monoclinic Amphibole.*—In several of our preparations of magnesium silicate which had been crystallized by more or less rapid cooling, small quantities of a twinned monoclinic form were observed, whose properties, with the exception of the extinction angle, were similar to those of the orthorhombic amphibole (the fourth form which is described under IV). Later, in studying the action of water on the latter substance at 375°–475°, we observed the constant recurrence of this monoclinic amphibole in larger amounts than in the original preparations; when, however, the amphibole was heated alone to considerably higher temperatures (above 900°) no such transformation took place. The change with water was always quite incomplete, but further experiments, it is hoped, may point the way to satisfactory conditions of formation.

Properties of Monoclinic Amphibole.—The crystallites of the monoclinic magnesian amphibole were invariably microscopic in size and too small to admit of a satisfactory study of their optical constants. Their direction of elongation is the prism axis, with which they extinguish at a small angle. In polysynthetically twinned fragments, a maximum extinction angle $c : c = 11°$ was observed, though smaller angles, 4°–8°, were noticed more frequently. The average refractive index

* The writers are indebted to Dr. G. P. Merrill of the National Museum for these specimens.

is very nearly equal to that of the orthorhombic amphibole ($\beta = 1{\cdot}585$), while the birefringence is not strong and is of the same order of magnitude as that of the orthorhombic form. The crystals, like those of the orthorhombic amphibole, are not so clear and transparent as the higher refracting pyroxenes, often showing distinct lines of growth; the twinning lamellae are usually fine and less sharply defined than in the monoclinic pyroxene. Intergrowths of the orthorhombic and monoclinic amphiboles were also observed occasionally, though they were distinguished with less certainty than in the pyroxenes.

The change of the orthorhombic to the monoclinic amphibole with water at temperatures of 375°–475° did not yield any well-formed crystals; the product appeared to be rather the result of a paramorphic change in the solid state. In the hope of getting individually developed crystals, we attempted the synthesis of this form from magnesium salts and soluble silicates or silica, and succeeded in getting a product with optical properties similar to those of the magnesian amphiboles, but in fibers so small that it was impossible to say whether they were orthorhombic or monoclinic. In view, however, of the partial change of the former into the latter, it seems probable that they were monoclinic.

Experiments in the Synthesis of the Amphibole at Low Temperatures.—Chrustschoff, some years ago, published a description of a method for the formation of hornblende in which a mixture of silicic acid, alumina, lime, magnesia, ferrous and ferric oxides, and the alkalies, partly in solution, partly precipitated, were heated in sealed glass vessels at a temperature of 550° for three months.*

It seems to us that glass vessels of such extraordinary properties deserve to be better known, and that the experimenter should have given some details concerning them, especially where they can be obtained, together with some information about his temperature measurements.

The experiments which we shall describe were done in a steel bomb 16^{cm} long, $2{\cdot}7^{cm}$ internal diameter, and $1{\cdot}4^{cm}$ thick, which was made by boring out a piece of steel shafting. The bomb was closed by a plug also of steel having a total length of 8^{cm}, the screw of which was 4^{cm} in length and fitted into a thread cut in the end of the bomb. A tight joint was insured by a washer of annealed copper 3 or 4^{mm} thick. The steel surfaces in contact with it were planed smooth, and into each were cut a number of very narrow concentric grooves about half a millimeter deep. To close the bomb, the plug was

* Comptes Rendus, cxii, p. 677, 1891.

screwed in by a long heavy wrench until the copper filled the grooves. A new washer should be used for each experiment. The capacity of the bomb was great enough to admit a cylindrical platinum crucible holding about 30^{cc}. Temperature measurements were made by introducing an insulated thermo-element into a 7^{mm} hole in the plug, the end of which it reached within 5^{mm}. The source of heat was a Bunsen burner. To distribute the heat more evenly, the bomb was surrounded by a collar of asbestos and sheet iron with a hole on the under side through which the flame passed. The joint was shielded from the latter by an annular asbestos disk which was slipped over it.

For the synthesis of the amphibole, the magnesium was taken in soluble form, either magnesium-ammonium chloride or a mixture of magnesium chloride with a sodium bicarbonate solution; while the silica was used in the amorphous state or in combination as sodium metasilicate. Generally ·25 or ·50 gram of magnesia was dissolved in the equivalent quantity of hydrochloric acid, then the ammonium chloride or sodium bicarbonate was added, and finally the silica or sodium silicate. This mixture was poured into the platinum crucible with 25^{cc} or more of water, covered, and put into the bomb, which was then closed tight and heated from 3 to 6 days at temperatures ranging from 375° to 475°. Although in the course of these experiments the details were varied considerably, we were only able to ascertain that the products formed at the higher temperatures were usually better crystallized.

When the bomb was opened, it generally contained more or less water, sometimes several cc.; the inner wall of the bomb itself was coated with magnetite, and sometimes the platinum crucible was covered with beautiful octahedra of the same mineral. In some experiments in which the water was nearly all gone, the bomb showed when cold an internal pressure and the odor of ammonia was noticeable.

After removal from the bomb, the products were washed and dried. To the naked eye they were all much alike; they were white, and of a tough and spongy texture. Optically they left much to be desired.

They were mostly crystalline but invariably fine-grained, often cryptocrystalline, and had to be studied rather in the aggregate than in individual fibers. In all these preparations the substance present in predominant quantity consisted of complex groups of fibers which extinguished parallel to their elongation, this direction being that of the least ellipsoidal axis c; their refractive index was less than 1·60 and agreed with that of the magnesium amphibole, so far as such minute fibers admit of measurement. The birefringence was low.

In addition to this substance small amounts of both the orthosilicate and quartz were observed. The crystals of the former were frequently well developed and exhibited the characteristic crystal habit of fosterite; they extinguished parallel to the prism edge, had an average refractive index of about 1·66, and much stronger birefringence than either the metasilicate or quartz.

The quartz crystals were ordinarily very small and recognizable only by their refractive index. In one preparation, however, where the sodium silicate in the form of large lumps was heated with magnesium ammonium chloride for 3 days at 400°–450°, numerous quartz crystals were found, the longest of which measured nearly 3^{mm}. They were water-clear, doubly terminated, sharply defined crystallographically, and resembled crystals of the natural mineral. Both optical and crystallographic measurements were made on these crystals, the results of which have been described at length in another paper* on the minerals of the lime-silica series.

In the products much of the material was too fine even for approximate determinations and may have contained other substances than the three cited above. It is noteworthy, however, that the pyroxene form of the metasilicate was not produced, but apparently the low refracting amphibole.

IV.—*Orthorhombic Amphibole. Kupfferite.*†—If magnesium silicate be melted and cooled without any special precautions, there may usually be detected, under the microscope, in the crystallized product, patches of a substance which differs markedly in appearance from either of the forms I and II. The fact that it occurred more frequently in the outer zones of the mass near the walls of the crucible, led to the suspicion that rapid cooling favored its formation. Experience soon proved the correctness of this conjecture. After a very considerable amount of work on the conditions necessary for its formation, we find (1) that the mass must be cooled rapidly, but not so rapidly as to form glass; and that (2) for this reason, probably, the quantity of material must not be too large. A satisfactory rate of cooling is attained if a platinum crucible containing 15 or 20 grms. of the molten silicate is quickly drawn from the furnace and held, uncovered, by the operator until crystallization is complete. If the hot crucible be set at once on a tile,

* Day, Shepherd and Wright, The Lime-Silica Series of Minerals, this Journal, xxii, Oct., 1906.

† The name Kupfferite was applied originally to the natural monoclinic amphibole of this composition. In the course of time, however, the name has been shifted to designate the orthorhombic form of the same composition and like enstatite represents the pure magnesium member of the amphibole series kupfferite-anthophyllite. Hintze, however, objects to this change. Compare, Hintze, Handbuch d. Mineralogie, Bd. II, p. 1196, and E. S. Dana, System of Mineralogy, p. 384–385, 1900.

the cooling is less rapid and the monoclinic pyroxene and enstatite are more likely to form. In the above way we succeeded in one instance in crystallizing 27 grams of the silicate entirely to amphibole. Ordinarily, however, a charge of this weight cannot be cooled with sufficient rapidity to prevent crystallization of more stable forms.

Our observations appear to have established the fact that the amphibole is more likely to crystallize from the melt if the initial temperature is much above the melting point. The experiments were made in a Fletcher furnace and temperatures were roughly measured by means of a thermoelement placed under the hood where the combustion gases emerge. Only rough relative measurements were necessary. The variation in the crystalline product with the initial temperature to which the charge is heated before cooling, is given in the following table:

TABLE VI.

Influence of the Initial Temperature of the Liquid on the Product of Crystallization.

Temperature in the top of the Fletcher furnace.	Charge.	Product obtained.
1430°	6 gr.	Silicate not melted.
1470	50 "	Just begins to melt.
1470	18 "	Charge had just begun to melt.
1480	6 "	Amphibole.
1485	6 "	Monoclinic pyroxene.
1490	6 "	" "
1500	6 "	" "
1500	6 "	" "
1500	6 "	" "
1500 –1510°	6 "	Amphibole.
1510	27 "	"
1520	50 "	Monoclinic pyroxene.
1525	8 "	Amphibole.
1530	6 "	"
1530	8 "	"
1530	12 "	Delay in removing the cover about three-fourths amphibole; one-fourth monoclinic.
1530	18 "	Amphibole and a little glass.
1535	6 "	Amphibole.
1535	6 "	"
1540	12 "	Amphibole and a little glass.
1545	12 "	Amphibole.

Tollens* found that the unstable form of monochloracetic acid crystallized with greater certainty if the liquid was first

* Tollens, Chem. Ber., xvii, i, 664, 1884.

raised considerably above the melting point, and Lehmann* states that benzyl-phenyl-nitrosamine also yields an unstable form when *strongly heated* and very rapidly cooled.

We have proved that (pp. 402 and 411), all other forms of magnesium silicate change into the monoclinic pyroxene before the melting point is reached. If the crystal structure depends on crystal particles or units which consist of regularly arranged chemical molecules, it is not impossible that some of these groups might preserve their identity some time after fusion of the substance, and become completely disintegrated only after some lapse of time or at a higher temperature. The favorable influence of a high initial temperature on the formation of amphibole would then be due to the complete breaking down of nuclei which condition the crystallization of the monoclinic form.†

We tried the effect of dropping small portions of the solid amphibole into the undercooled liquid in order that they might serve as nuclei for crystallization, but the experiment did not succeed. The silicate liquids are so viscous that the nuclei do not seem to exert any influence on the crystallization. The negative effect of nuclei is very strikingly brought out in the following way: Magnesium silicate can be chilled in such a manner as to yield radial spherulites of monoclinic pyroxene embedded in glass. Now when this cake is heated again at 900°, not only do the existing nuclei fail to grow, but they exercise no orienting influence on the new crystals which form.

As this substance has not been obtained before, some further details regarding its crystallization may be of interest. It usually begins on the upper surface of the melt next to the walls of the crucible, forming a fringe of converging fibers which grow toward the center, though sometimes a number of rather widely separated nuclei start at points on the upper or lower surface. This crystal form is characterized by a considerably slower growth than the monoclinic. If, in a crucible in which the amphibole has already begun to crystallize, the still liquid portion be touched by a wire, the disturbance is instantly followed by the appearance of a monoclinic nucleus. The difference in the rate of growth of the two crystal forms is then very striking. We early noticed a very marked difference in the rise of temperature during the crystallization of these two forms, the monoclinic raising the temperature to a dazzling white; and though the difference must be partly due

* O. Lehmann, Molekularphysik, vol. i, p. 211.

† A similar conception has been advanced in a paper by Day and Allen to explain the superheating of the alkaline feldspars. This Journal, series (4), xix, p. 124, 1905.

to the rapidity of the process, we were led to suspect what afterwards proved true, that the amphibole would pass over into the other with evolution of heat. This and the method of its formation by sudden cooling are characteristic of monotropic forms.

Interesting results were obtained in an attempt to measure the approximate temperature at which the amphibole crystallizes. As a determination of a physical constant the attempt failed, because the disturbance caused by touching the liquid with the element was sufficient to start the crystallization of the monoclinic form in every instance. The following trials were made with the bare thermoelement dipped directly into the liquid, which above 1100° is easily penetrable with a wire.

Experiment 1.—As soon as crystallization began, the element was dipped into the center of the charge. Temperature 1350°. All monoclinic pyroxene.

Experiment 2.—Amphibole started to crystallize in the outer zone. Measurement as in 1. Temperature 1300°. Monoclinic pyroxene started at once.

Experiment 3.—Same as 2. Temperature 1300°.

Experiment 4.—Amphibole began to crystallize on the upper surface next the crucible wall as in 2. The element was dipped in, on the boundary line, between solid and liquid, about 1^{cm} from the crucible wall. Temperature 1150°. Monoclinic pyroxene started instantly.

Experiment 5.—Amphibole began to crystallize as usual. We waited until it nearly covered the surface and then dipped the element into the liquid, which remained in the middle. Temperature 1180°. When the charge was removed from the crucible, all but the upper layer proved to be monoclinic pyroxene.

Experiment 6.—Like Experiment 4. Temperature 1165°.

The rise of temperature with crystallization, the rapid radiation of heat from an unprotected crucible, the variation of temperature in different parts of the mass, all prevent anything better than rough temperature estimates, but the fact that the amphibole forms in a region near which a slight disturbance is sufficient to crystallize the glass to monoclinic pyroxene, is conspicuous and important. This temperature has been shown in an earlier part of the paper to be above 1150°.

Properties of Orthorhombic Amphibole.—This amphibole appears white and porcelain-like, and crystallizes in radial spherulites and fibrous aggregates. Since we have not yet been able to obtain crystals suitable for measurement, its identification rests solely on the correlation of its other properties, chiefly optical, with those of the natural mineral, kupfferite.

The fibers were too fine and too intimately intergrown to

show the cleavage plainly, still in a number of cases where fibers were tilted to a vertical position under the microscope an indistinct cleavage of about 120° was observed. Their hardness is 6. In transmitted light the aggregates do not appear so clear and transparent as the pyroxenes, but are usually of a pale brown color. The refractive indices were measured by the method of refractive liquids: $\gamma = 1{\cdot}591 \pm {\cdot}003$, $\alpha = 1{\cdot}578 \pm {\cdot}003$, $\beta = 1{\cdot}585 \pm {\cdot}004$. Birefringence is not strong, ·013 approximately, and the interference colors are confined to the bright tints of the first and second orders. The extinction is usually parallel to the direction of elongation, although in a few sections a small extinction angle, $c : c = 3°$–$6°$, was observed, indicating intergrowths of orthorhombic and monoclinic amphiboles similar to those observed in nature. The plane of the optic axes lies parallel to the long direction; the optic axial angle is large and the optical character apparently positive, determined on a section nearly perpendicular to an optic axis. The pleochroism is c = brown, and b lighter brown; absorption, $c > b$.

Lines of growth are often distinct within the crystallites and exhibit a plumose arrangement.

Although the above optical data do not suffice to prove definitely that this form of magnesium metasilicate is an amphibole, they do agree closely with the properties of the orthorhombic amphibole of similar composition found in nature. Unfortunately, the definite solution of this question must be deferred until after means have been devised to produce measurable crystals.

The specific gravity was determined on several different preparations, two of which (I and II) were very carefully examined microscopically and found to be practically pure; the third, having been observed by the same method to contain small quantities of glass and the monoclinic form, was separated with great care by heavy solutions (methylene iodide and benzene), the separation of each portion being twice repeated and controlled by the microscope.

Specific gravity at 25° C.

Prep. I.	Prep. II.	Prep. III.
2·858	2·860	2·855
2·856	2·860	2·853
2·857	2·860	2·854
Average,		2·857

Transformation of Orthorhombic Amphibole by Heat.—The orthorhombic amphibole changes, like enstatite, and somewhat more rapidly, into the monoclinic pyroxene, when heated to a sufficient temperature. Here, too, the change is sluggish, as the following table indicates:

TABLE VII.

Change of Orthorhombic Amphibole to Monoclinic Pyroxene.

Time.	Temperature.	Observations.
1 day	1020°–1040°	No change.
2 days	1055 –1077	Indications of slight change.
20 hours	1100 –1100	No change observed.
18 hours	1120 –1140	Fragments dotted with pyroxene.
3 days	1127 –1153	All changed.
18 hours	1144 –1173	Partly changed.
2 days	1150 –1183	All changed.

It is possible that at the lower temperatures the amphibole passes into enstatite; the product is there so fine-grained that a microscopic distinction between the two pyroxenes cannot be made.

PART II.—RELATIONS OF THE DIFFERENT FORMS TO ONE ANOTHER.

Stability relations.—The four forms of magnesium silicate having thus been prepared and studied in detail, the question of their relative stability arises. It is well known that a substance chemically homogeneous may exist in several different physical forms, which are called polymorphic when they yield identical liquids, solutions and vapors, in which case their chemical molecules, in distinction from those of isomers, are identical. Polymorphic substances are enantiotropic when, by heating, one form changes without melting into the other at a definite temperature called the inversion point, and on cooling again the reverse change takes place. In this case, the first form is stable below the inversion point only, the second above it. The form stable at lower temperatures inverts to the other with absorption of heat, and the reverse change takes place with evolution of heat.* An instance of the enantiotropic relation is the mineral wollastonite, which inverts at about 1190°, with absorption of heat, into a second form, pseudo-hexagonal in symmetry.

In another class of polymorphic substances there is no such inversion point, and one of the forms is more stable than the other at all temperatures below the melting point. These relations are best expressed by diagrams.

* Given the relations of the vapor pressures, this follows from the second law of thermodynamics. Van't Hoff, Vorlesungen über Theoret. u. Phys. Chemie, Braunschweig, 1901, ii, 128.

Enantiotropy.—In fig. 7,

OT = axis of temperatures.
OP = axis of vapor pressures.
abc = vapor tension curve of liquid.
ed = vapor tension of solid stable below T_2.
db = vapor tension of solid stable above T_2.
T_2 = inversion point.
T_1 = melting point of form stable above T_2.

7

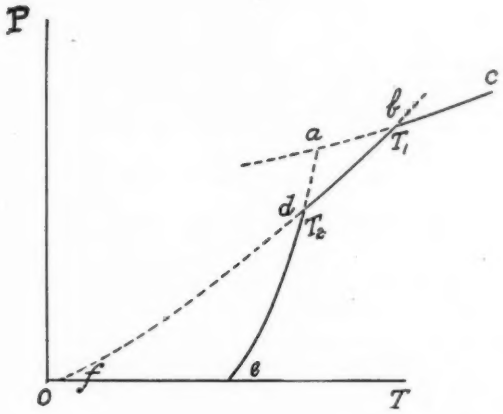


FIG. 7. Vapor pressure curves in a case of enantiotropy; *ed* is curve of solid stable below T_2; *db* is curve of solid stable above T_2. The full lines represent a condition of stability, the dotted lines a condition of instability.

The two curves *ed* and *fb* intersect at *d* below the melting point curve. At this point the two forms have the same vapor pressure, and are therefore in equilibrium, and the temperature, T_2, is the inversion point. Likewise, the point T_1 is common to two curves, *bd* of the solid stable at higher temperatures, and *ac* of the liquid; at that point, therefore, this solid and the liquid are in equilibrium, and T_1 is the melting point. Since in general the curve *ed* cannot be prolonged so as to intersect with the curve *ac*, the solid stable at lower temperature usually has no melting point. *bd* can usually be prolonged to low temperatures by sudden cooling or otherwise, a fortunate circumstance without which nearly all physical and chemical data upon the solids stable only at high temperatures would be unattainable.

Monotropy.—In fig. 8,

OT = axis of temperatures.
OP = axis of vapor pressures.
abcd = vapor pressure curve of liquid.
eb = vapor pressure curve of unstable solid.
fc = vapor pressure curve of stable solid.
T_1 = melting point of stable form.
T_2 = melting point of unstable form.

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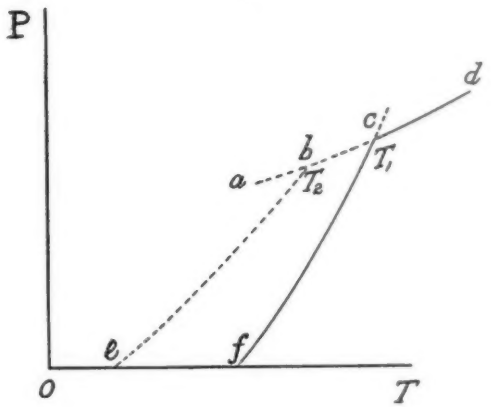

FIG. 8. Vapor pressure curves in a case of monotropy; *eb* is curve for unstable form; *fc* is curve for stable form.

This figure represents the relations between the vapor pressure curves of two monotropic solids and their corresponding liquid. The curve differs from the preceding case only in that *fb* and *ed* do not intersect before reaching the melting point curve *abc*. At *b* the vapor pressure of one solid is equal to that of the liquid, and the two are in equilibrium; T_2 is therefore the melting point of this form. Similarly, T_1 is the melting point of the second (stable) solid. It will be noted that for a given temperature the vapor pressure of the first solid is always greater than that of the second; the two curves do not intersect below either melting point and therefore are not in equilibrium at any temperature; the solid of lower vapor pressure is more stable than the first throughout. The melting point of the unstable solid is always lower than the other, but in practice the unstable form often changes into the more stable before its own melting point (T_2) is reached.

Although many solids, like the minerals under discussion, have a vapor tension much too low for measurement at these temperatures, the relations are as represented in the diagram.*

The stability relations of the four polymorphic forms of magnesium silicate may be shown in the same way by a simple diagram (fig. 9). These curves do not, of course, represent measured vapor pressures, but simply the order of the stability

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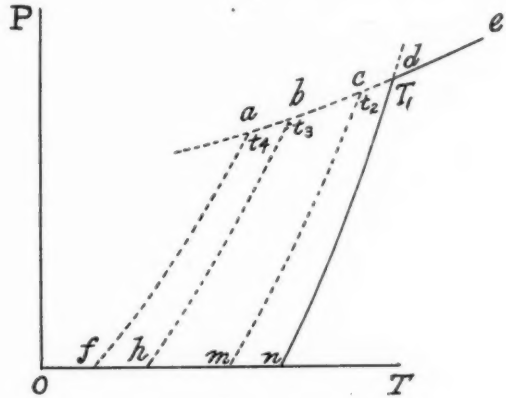

FIG. 9. *fa* is vapor pressure curve for orthorhombic amphibole; *hb* is vapor pressure curve for monoclinic amphibole; *mc* is vapor pressure curve for orthorhombic pyroxene; *nd* is vapor pressure curve for monoclinic pyroxene.

of the forms. As is proved by the experiments described below, the monoclinic pyroxene, at atmospheric pressure, is the most stable, and the others bear a monotropic relation to it, their relative stability being in the order indicated by the vapor pressure curves.

Two lines of evidence lead to this conclusion: (1) *a*. Enstatite and the amphiboles, while still in the solid state, pass over at high temperatures into monoclinic pyroxene which cannot be changed back without passing through the amorphous state; *b*. At much lower temperatures (about 800°) the same three forms can be dissolved and recrystallized simultaneously into the monoclinic pyroxene by means of fluxes; (2) enstatite and the two amphiboles change into monoclinic pyroxene with evolution of heat.

(1) Although it was shown conclusively that the amphiboles change into monoclinic pyroxene above about 1150°, and

* Roozeboom, Heterogen Gleichgewichte, Heft. 1, 158–159, Braunschweig, 1901.

enstatite changes to the same form above 1260°, and that on cooling neither of the changes is reversible, these facts in themselves do not prove monotropy. In certain cases of enantiotropy, mere cooling of the form stable at high temperatures does not suffice to revert it to the other form, even when both forms are in contact and unlimited time is allowed.* This inertia is apparently due to the great internal friction between the molecules at temperatures below the inversion point. The molecular immobility may be overcome by the use of suitable fluxes in which solution of the unstable form and precipitation of the stable go on hand in hand, the unstable form being the more soluble. Thus pseudo-wollastonite is less stable than wollastonite below the inversion point, yet it does not revert to it at lower temperatures except by the aid of proper solvents. In this case, molten calcium vanadate proved well adapted to the purpose. The pseudo-wollastonite dissolved in it and cotemporaneously wollastonite crystallized out.

Similar tests with solvents were applied to the different forms of magnesium silicate with the result, as we have already recounted in detail (pp. 387 et seq.), that from a considerable number of solvents magnesium silicate was found to pass into solution and gradually to crystallize, invariably as monoclinic pyroxene, whatever crystal form was originally taken. This indicates that at atmospheric pressure the monoclinic pyroxene is the most stable form of magnesium silicate at all temperatures between about 800° and the melting point of the monoclinic form (1521°).

(2) In order to confirm this evidence of monotropy, we sought to ascertain the direction of the heat changes, whether exothermic or endothermic, for two of the unstable forms. The method first tried was that of Frankenheim, which consists in observing at regular intervals the rise in temperature of a mass of the substance. Heat was supplied by means of the electric resistance furnace used in this laboratory, and the temperature measured by a thermoelement.† The curves thus obtained by heating the different forms are perfectly smooth, showing neither absorption nor release of heat until the melting point of the monoclinic form is reached. The fact that all forms seem to have the same melting point indicates in itself that the other forms change into the monoclinic pyroxene before melting. The change, however, is so sluggish that it proceeds throughout a temperature interval of several hundred degrees, and the heat is therefore so uniformly distributed as not to be indicated by the curve.

*See "Wollastonite and Pseudo-Wollastonite," this Journ. ser. 4, xxi, p. 95, 1906.

†Day and Allen, Phys. Rev., xix, 184.

New Method for Detecting the Direction of Sluggish Heat Changes.—A substance in which a transformation progresses so slowly that the accompanying heat change cannot be detected by the ordinary method, should show it plainly if the change could be forced to proceed with sufficient velocity. The heat change would then be concentrated and become visible on the temperature-time curve.

In changes of this character, the rate of change depends on the temperature, and increases rapidly with it. If, therefore, a substance which is unstable at high temperatures be introduced into a furnace which is several hundred degrees above the lower limit of the unstable region, the heat effect is in general easily followed. In our experiments the apparatus shown in fig. 10 proved very satisfactory for the purpose. An empty platinum crucible is first placed on a pedestal of refractory material in the electric resistance furnace. The unglazed porcelain tube, A, 1^{cm} in inside diameter and open at both ends, passes through holes drilled in the two covers, B and B′, and is then clamped in the position shown in the figure, the lower end of the tube reaching down to the top of the crucible. The thermoelement C is covered by a platinum shoe, D, which should occupy the same position in all the experiments, i. e., about the center of the charge. This is assured by clamping the tube in a fixed position and fastening the element securely to it by platinum wire. Care was taken to obtain like conditions in each experiment, especial attention being given to fitting together the parts of the furnace to obtain minimum radiation of heat, and in placing the crucible and thermoelement in the same relative position for each experiment.

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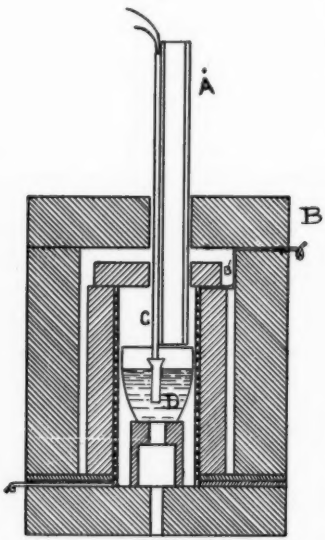

The furnace is now brought to a constant temperature, which should be sufficiently high to insure a rapid change of state. In the particular substances which we investigated, temperatures ranging from 1425°–1475° were found best adapted to show the heat effect. A weighed portion of the substance (40

or 50 grams) is then quickly dropped through the tube into the crucible, after which temperature readings are made at half-minute intervals until the temperature of the crucible again becomes practically constant.

In a second experiment under the same conditions, the product of this first change is introduced into the furnace as before, and a second temperature curve determined under exactly the same conditions. A comparison of the two curves plainly indicates the direction of the heat change. If an evolution of heat has taken place, the temperature rate is accelerated and the curve of the unstable body lies to the left and above that of the stable form, as shown in curve I of fig. 11. On the other hand, if there has been an absorption of heat, the temperature rate is retarded and the curve of the unstable form lies to the right and below that of the stable form.

In order to test the method, substances were first tried in which the direction of heat change was known, e. g., wollastonite, which passes into pseudo-wollastonite with absorption of heat; wollastonite glass, which crystallizes with evolution of heat; and albite, which melts with absorption of heat,—all very slow changes. Fig. 11 contains the results obtained with wollastonite and wollastonite glass. The number of curves in a single figure and their general similarity of form have made it inadvisable to confuse the figures by attempting to show the observed points on each curve. The observed electromotive forces in microvolts are therefore tabulated separately (Table VIII). The corresponding temperatures are not important, as the point which we desire to establish depends merely upon the relative displacement of that portion of the curve in which a change of state may be expected to occur. The curves II are heating curves for pseudo-wollastonite, which is the stable form at the temperatures of the experiment, and therefore suffers no change of state. Curve I, the corresponding curve for wollastonite glass, lies to the left and above the curves for pseudo-wollastonite, and plainly indicates an evolution of heat, since all other thermal conditions are identical in the two cases. The curves for wollastonite, III, lag behind those for pseudo-wollastonite, and indicate heat absorption. The results for albite and albite glass are shown in fig. 12 (Table IX). It is interesting to compare these results for albite with those obtained for orthoclase (which resembles albite very closely in its thermal properties), in a previous investigation in this laboratory by the Frankenheim method (fig. 13).*

*Arthur L. Day and E. T. Allen, "The Isomorphism and Thermal Properties of the Feldspars," this Journal, series 4, xix, 93, 1905.

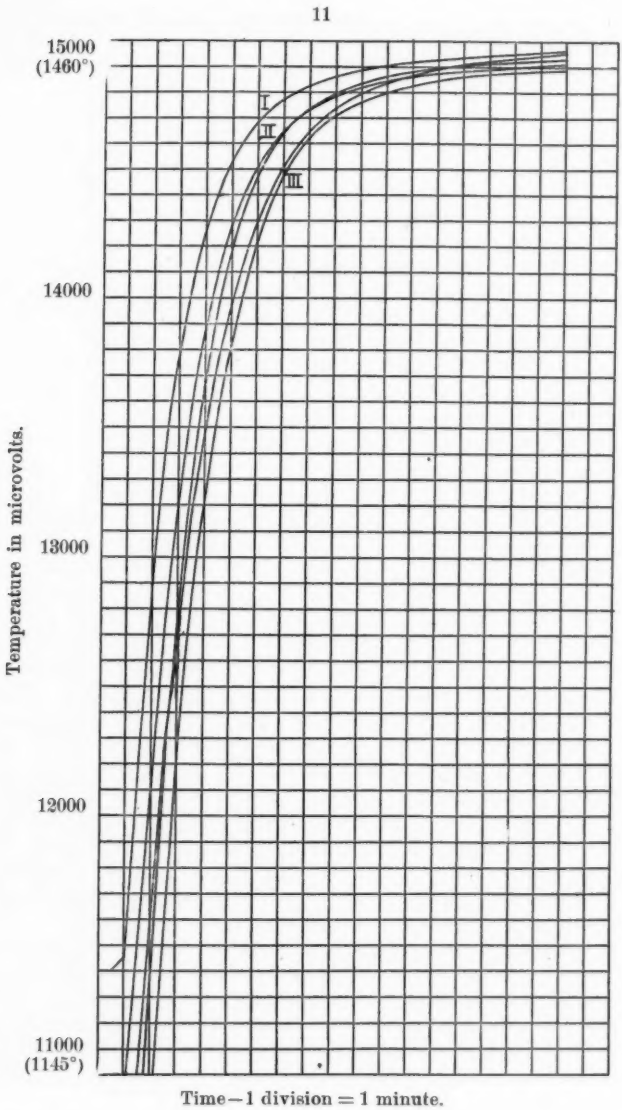

FIG. 11. I = Wollastonite glass (one curve).
II = Pseudo-wollastonite (two curves).
III = Wollastonite (two curves).

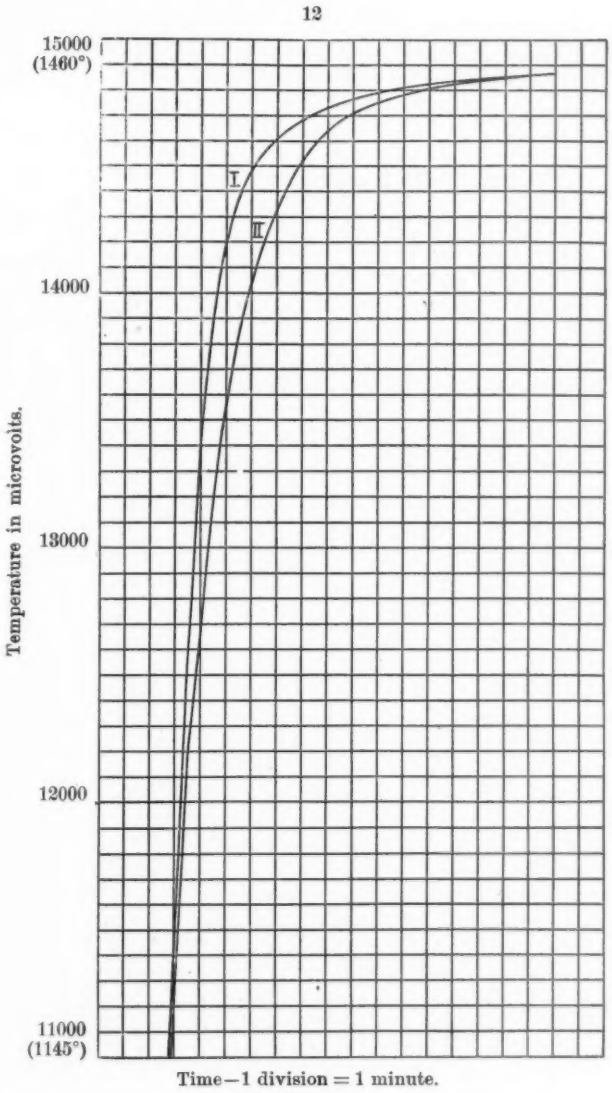

FIG. 12. I = Albite glass.
II = Albite.

The curves in this figure (fig. 13) were obtained by heating large charges (about 100 grams) of orthoclase to a temperature which caused a complete change of state. During the time of melting, which, in the alkaline feldspars, extends over quite an interval, the rate at which the temperature rises is retarded by heat absorption, but the change is so slow that this retardation is very slight. The indentation in the curve is

TABLE VIII (see fig. 11).

Time.	Wollastonite glass.	Pseudo-Wollastonite.		Wollastonite.	
0 min.	15000	15000	15000	15000	15000
	11400	11300	10600	9900	11100
1 "	11450	10905	9960	9170	10380
	12210	11450	10520	9700	875
2 "	12890	12115	11350	10585	11560
	13445	734	12175	11495	12215
3 "	790	13208	790	12245	715
	14065	595	13305	12840	13160
4 "	262	880	680	13215	484
	418	14114	970	550	760
5 "	529	281	14185	818	974
	619	416	350	14050	14154
6 "	683	514	474	225	292
	732	593	570	368	414
7 "	770	650	641	473	506
	801	696	695	558	585
8 "	825	731	738	620	646
	845	761	772	670	696
9 "	861	784	798	706	736
	875	801	819	735	770
10 "	885	816	835	759	795
	895	829	850	780	818
11 "	903	840	862	798	837
	911	850	872	812	851
12 "	917	858	880	824	867
	923	865	887	835	879
13 "	927	872	893	844	889
	932	877	899	852	899
14 "	937	882	904	859	907
	940	888	908	864	915
15 "	944	891	912	869	921
	948	895	915	873	928
16 "	951	898	919	877	933
	953	901	921	880	939
17 "	956	904	924	883	945
	961	908	927	885	950
18 "	964	911	929	887	954

TABLE IX (see fig. 12).

Time.	Albite glass.	Albite.
0 min.	15000	15000
	11100	11850
1 "	9900	315
	9900	720
2 "	10525	12250
	11430	800
3 "	12365	13140
	13145	478
4 "	695	716
	14075	919
5 "	300	14080
	448	221
6 "	543	334
	610	432
7 "	659	513
	699	584
8 "	727	636
	751	676
9 "	770	705
	785	728
10 "	800	747
	811	761
11 "	821	772
	830	782
12 "	838	790
	844	797
13 "	850	803
	855	809
14 "	859	813
	864	818
15 "	868	821
	872	825
16 "	876	828
	880	831
17 "	882	834
	885	837
18 "	887	840

made evident to the eye by continuing as a dotted line the course the curve would have followed, had no absorption of heat occurred.

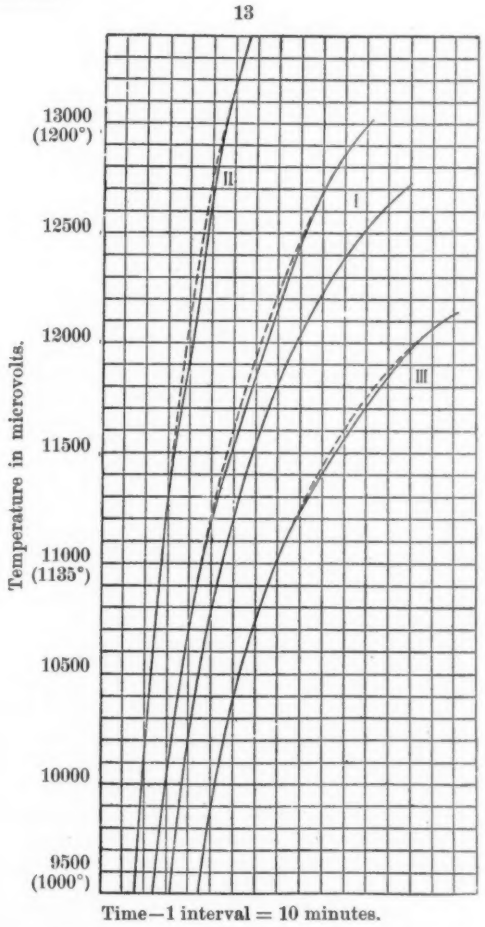

FIG. 13. Curves showing heat absorption in melting orthoclase.

Figures 14–18 (Tables X–XIV), show the curves obtained by the new method on the different forms of magnesium metasilicate. The curves for the orthorhombic amphibole, enstatite and monoclinic pyroxene in fig. 14 (Table X) were obtained in preliminary experiments, and are less accurate than those obtained in the later experiments, due to the fact that the posi-

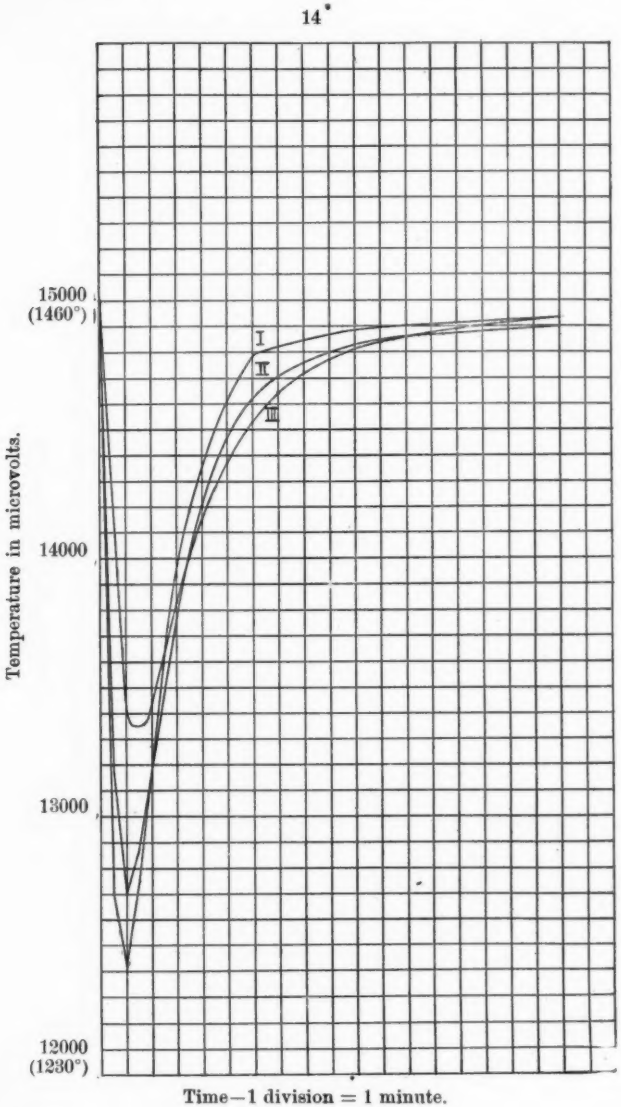

FIG. 14. I = Orthorhombic amphibole.
II = Enstatite.
III = Monocline pyroxene.

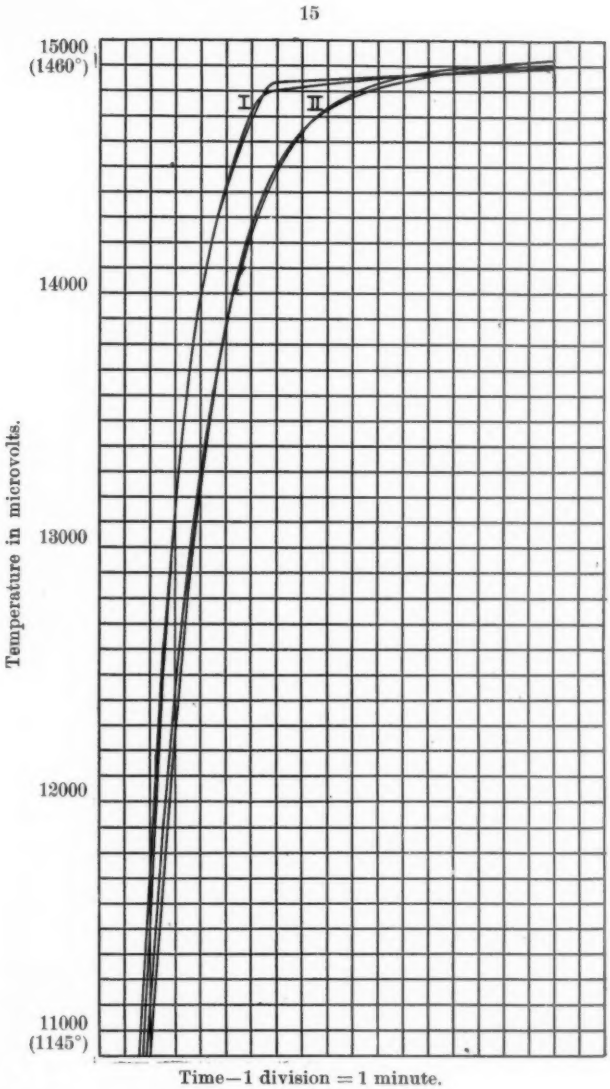

FIG. 15. I = Orthorhombic amphibole (two curves).
II = Monocline pyroxene (two curves).

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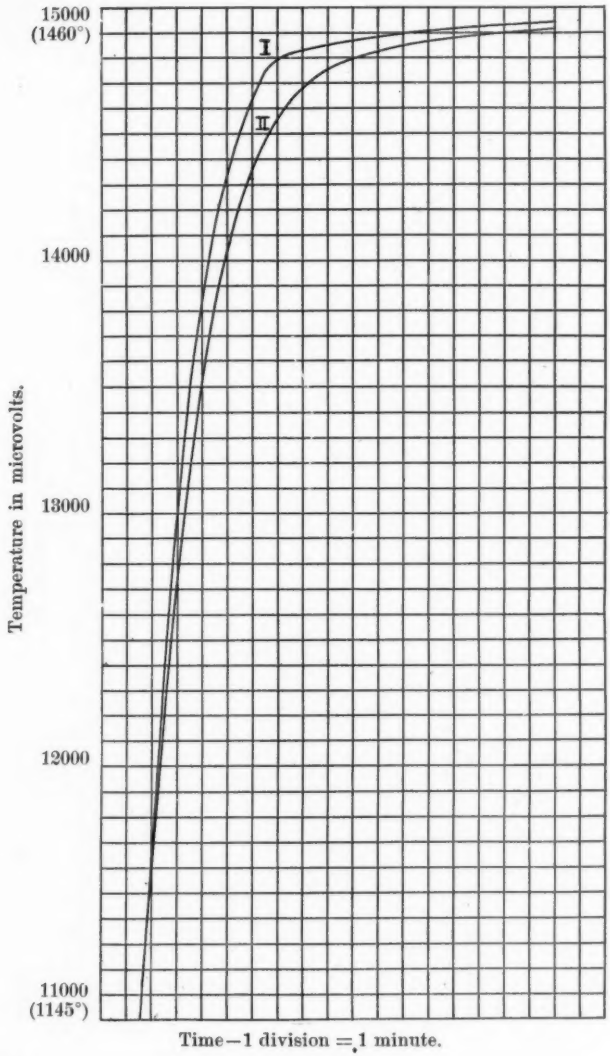

FIG. 16. I = Orthorhombic amphibole.
II = Monoclinic pyroxene.

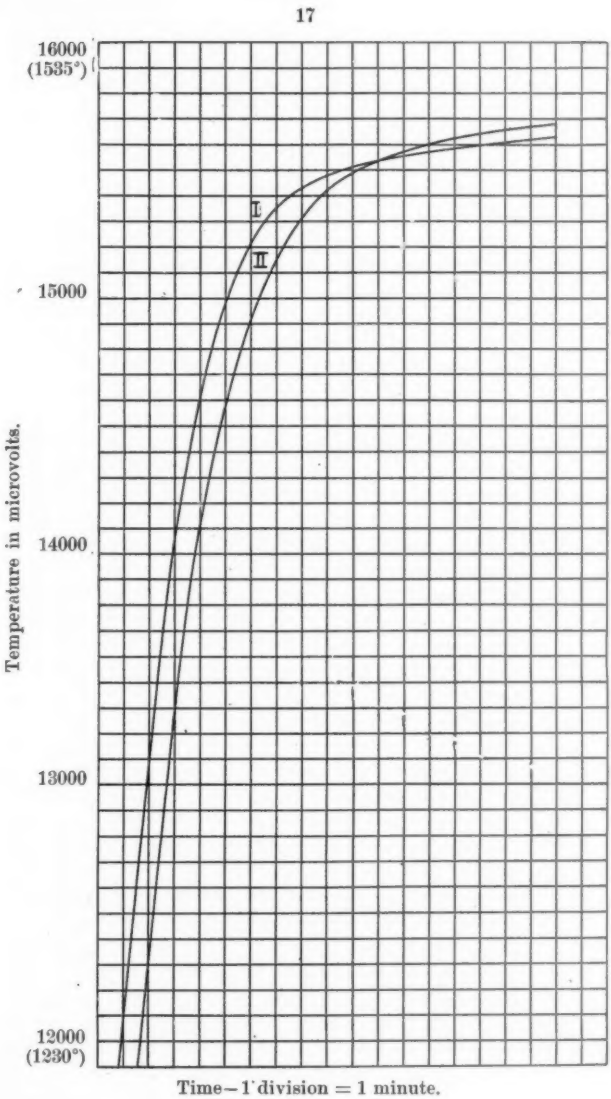

FIG. 17. I = Enstatite.
II = Monoclinic pyroxene.

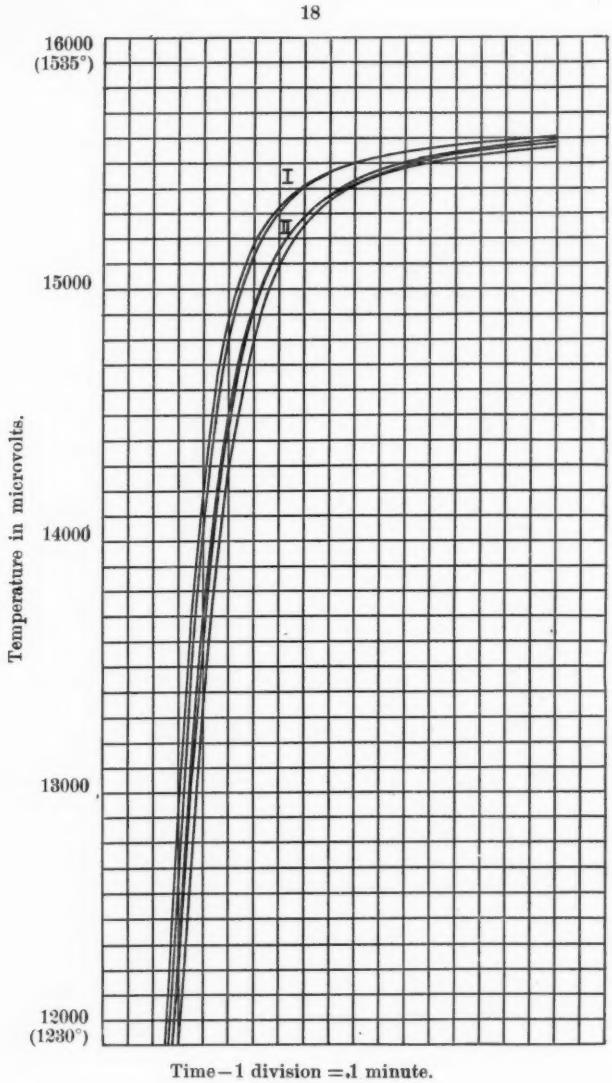

FIG. 18. I = Enstatite (two curves).
II = Monoclinic pyroxene (three curves).

TABLE X (see fig. 14).

Time.	Monoclinic pyroxene.	Amphibole.	Enstatite.
0 min.	15000	15000	15000
		12700	13170
1 "	13500	415	12707
	350	750	870
2 "	440	13200	13175
	625	630	505
3 "	830	930	780
	14000	14180	14017
4 "	145	350	200
	265	495	353
5 "	370	600	466
	455	706	555
6 "	530	785	618
	590	803	671
7 "	640	814	708
	680	831	738
8 "	716	841	761
	745	855	781
9 "	770	869	796
	790	878	808
10 "	810	886	819
	825	876	834
11 "	837	873	847
	848	877	857
12 "	859	890	862
	869	892	864
13 "	876	894	863
	884	898	866
14 "	891	905	871
	898	910	876
15 "	903	913	881
	909	917	884
16 "	915		888
	920	923	890
17 "	926	926	893
	931		895
18 "	934	933	898

TABLE XI (see fig. 15).

Time.	Monoclinic.		Amphibole.	
0 min.	15000	15000	15000	15000
	11250	11000	10850	11050
1 "	10200	10003	9950	10200
	10520	10280	10560	770
2 "	11185	915	11530	11710
	870	11650	12460	12575
3 "	12435	12285	13120	13170
	915	830	640	655
4 "	13290	13257	980	990
	613	610	14230	14240
5 "	860	880	407	424
	14070	14100	557	585
6 "	235	266	688	716
	375	400	797	785
7 "	479	500	833	801
	566	579	839	807
8 "	630	639	839	814
	687	687	847	821
9 "	728	724	847	827
	763	755	852	832
10 "	789	778	859	838
	811	796	857	844
11 "	828	811	858	849
	843	825	862	854
12 "	855	837	865	859
	866	847	869	863
13 "	874	856	874	867
	881	865	881	870
14 "	886	871	880	874
	891	877	887	877
15 "	896	882	891	880
	903	886	893	883
16 "	908	889	895	885
	912	893	896	887
17 "	917	897	898	890
	921	901	900	892
18 "	924	904	902	894
	927			
	930			

tion of the thermoelement was less carefully adjusted, but the relative position of the curves is clearly established. Figures 15 and 16 (Tables XI and XII) contain curves for the same amphibole and monoclinic pyroxene, and figures 17 and 18 (Tables XIII and XIV) for enstatite and the monoclinic pyroxene, which represent the results of experiments made

TABLE. XII (see fig. 16).

Time.	Monoclinic pyroxene.	Amphibole.
0 min.	15000	15000
	10920	10600
1 "	343	170
	890	825
2 "	11570	11625
	12210	12380
3 "	740	995
	13180	13490
4 "	520	840
	815	14120
5 "	14040	332
	223	500
6 "	360	630
	476	739
7 "	559	795
	627	818
8 "	678	830
	720	841
9 "	751	850
	778	860
10 "	798	868
	811	876
11 "	825	884
	838	891
12 "	849	897
	857	903
13 "	863	908
	871	913
14 "	877	917
	883	921
15 "	888	924
	893	928
16 "	897	931
	905	933
17 "	909	937
	913	940
18 "	916	942

TABLE XIII (see fig. 17).

Time.	Monoclinic pyroxene.	Enstatite.
0 min.	15800	15800
	12100	12380
1 "	11160	140
	700	670
2 "	12325	13200
	940	690
3 "	13410	14065
	805	370
4 "	14115	615
	375	820
5 "	584	980
	768	15115
6 "	915	215
	15048	295
7 "	152	352
	242	394
8 "	312	428
	372	455
9 "	418	476
	458	495
10 "	489	510
	515	523
11 "	536	533
	557	543
12 "	572	551
	588	558
13 "	601	565
	612	573
14 "	623	580
	631	587
15 "	639	594
	647	600
16 "	654	606
	661	612
17 "	666	616
	672	623
18 "	678	628
		631

with all the precautions which we have prescribed. The curves for both the enstatite and the amphibole lie to the left and above that for the monoclinic pyroxene. They therefore change into the latter with evolution of heat, and hence are monotropic with respect to it. The curve for the orthorhombic amphibole lies outside that of enstatite, and consequently the exothermic change is quantitatively greater

TABLE XIV (see fig. 18).

Time.	Monoclinic pyroxene.			Enstatite.	
0 min.	15700	15700	15700	15700	15700
	8500		10100	9800	10000
1 "	8645	9520	9400	8715	9765
	9300	9915	9848	9325	10210
2 "	9930	10615	10605	10415	11035
	10905	11475	11515	11640	12010
3 "	11800	12270	12315	12620	890
	12630	13005	13075	13475	13658
4 "	13325	605	715	14065	14205
	890	14113	14170	510	615
5 "	14290	455	510	797	877
	555	228	763	15000	15055
6 "	808	915	938	135	179
	975	15052	15068	238	265
7 "	15095	152	161	308	324
	185	230	233	366	372
8 "	242	289	287	407	410
	309	337	331	443	443
9 "	357	374	365	468	462
	386	406	394	482	481
10 "	416	431	417		499
	440	453	437		511
11 "	458	471	454		523
	476	488	469		533
12 "	492	501	481		542
	504	514	492		551
13 "	514	525	503		558
	524	534	511		565
14 "	533	543	520		570
	541	551	527		575
15 "	548	558	533		579
	555	565	539		585
16 "	561	571	545		588
	567	577	550		596
17 "	572	582	555		600
	577	587	559		605
18 "	581	592	563		604
	585	597	568		

for amphibole, which indicates that it is the least stable of the three forms. As compared with the curve of wollastonite glass, the form of the (orthorhombic) amphibole curve is significant. The change of the former begins at a much lower temperature and forms a smooth curve, while the latter changes at higher temperatures and, as a result, the influence of the heat change continues until the maximum temperature is almost reached; consequently the curve shows a sharp change in direction near the top.

Although this method is purely qualitative, repeated trials on all these substances have convinced us that the relative position of the curves is invariable. No *point* of change, of course, can be found.

In the consideration of these curves the fact must not be overlooked that they include two quantities which may be independently variable, the heat of fusion or inversion and the specific heat. In general it is undoubtedly true, and therefore a justifiable assumption in this case, that latent heats are of a greater order of magnitude than specific heats. Although glasses possess higher specific heats than the solids which crystallize from them, polymorphic forms of the same substance in all probability possess similar specific heats. For the purposes here described, we are, therefore, perfectly safe in assuming that the comparisons made are independent of *differences* of specific heat in the substances experimented upon. The results obtained for albite by this method are in full accord with well established existing data, although albite, of all the substances examined, might be expected to offer difficulties from this cause. A substance exhibiting a sluggish heat change might perhaps be found in which the relative magnitude of the specific heats of it and its product, when compared with the latent heat of the change, would be such that the latter would have less influence on the form of the curve. In such a case, the method would lead to erroneous conclusions.

It goes without saying that if the change to be investigated does not take place during the time the substance is in the furnace, the method is useless. We found this true in the case of quartz. When the temperature of the furnace was held at 1560°, only about 1 per cent of the quartz was changed during the twenty minute period of experiment, even though other evidence has shown that tridymite is the stable form above a point at least as low as 800°.*

Order of Stability.—We have seen (pp. 402, 410 that the orthorhombic amphibole and enstatite both pass over into the monoclinic pyroxene under circumstances which point to the greater stability of the last named form; that the heat effect which accompanies this change of state is exothermic in all cases, but quantitatively greater in the change—amphibole ⟶ monoclinic pyroxene. The amphiboles are, therefore, less stable than enstatite, a conclusion which is substantiated not only by the greater difficulty of forming the amphiboles, but by the closer resemblance of all the properties of the two pyroxenes. The fact that the monoclinic amphibole probably forms directly from the orthorhombic amphibole in the presence of water at 375°–475°, though the orthorhombic form is all the while in

* Day, Shepard and Wright, loc. cit.

excess, indicates the greater stability of the former. In connection with this it should be noted that the two amphiboles resemble each other as closely as do the two pyroxenes, the monoclinic forms being the stabler in both cases. The order of stability of the four forms is represented in the diagram (p. 414).

Volume Relations.—Although theoretically there is no reason requiring it, the facts show that the specific gravities, and therefore the specific volumes, of the four forms of magnesium silicate lie in the order of their stability:

Specific gravity of glass	2·743
" " " orthorhombic amphibole	2 857
" " " monoclinic "	----*
" " " orthorhombic pyroxene	3·175
" " " monoclinic "	3·192

Geological Inferences.

Conditions of Formation of Meteorites.—It has been shown above, that the monoclinic magnesian pyroxene, though not generally recognized as a mineral, does occur in nature. After it had been found to be the stablest form of magnesium metasilicate, its occurrence seemed altogether likely. An examination of the literature then developed the fact that Fouqué and Lévy had already discovered it in meteorites.† Still their proof lacked one essential point; they assumed the composition of the mineral. The optical study of the material of the Bishopville meteorite, which has been shown to be practically pure magnesium silicate,‡ supplied the missing link in the chain: a careful measurement of all its important optical constants, and a comparison of these with the constants of our monoclinic form, established the identity of the two. Fouqué and Lévy state that in some meteorites the monoclinic form, in others the enstatite, is in excess. In the Bishopville and other meteorites, this form is intergrown with enstatite. In the similar intergrowths of enstatite with a "monoclinic pyroxene" so frequently observed in rocks, it is very probable that in some cases the latter has the same composition as the enstatite.

The parallel growths of enstatite and the monoclinic pyroxene which are characteristic of meteorites, we were able to reproduce by cooling a molten mass of pure magnesium silicate at a rather rapid rate. The slower the cooling, the more of the

* The specific gravity of this form has not been determined, because the substance has not been obtained free from other forms. Its average index of refraction is very close to that of the orthorhombic amphibole, but appears to be a trifle higher, so that we assume with some degree of probability that the specific gravities of the two amphiboles are related just as those of the two pyroxenes.

† Bull. Soc. Min., iv, 279, 1881.

‡ J. Lawrence Smith, this Journal (2), xxxviii, 225, 1864.

monoclinic form is obtained; hence we conclude that the Bishopville meteorite was probably cooled rather rapidly from a high initial temperature. The occurrence of similar intergrowths of the same minerals in many other meteorites indicates that the above mode of formation is a general one, though ferrous silicate, which is generally present, would lower the temperature of crystallization.

Occurrence of unstable forms of the metasilicate in nature.—Since the monoclinic magnesian pyroxene is the stablest form, the question naturally arises, why does it not occur more frequently in nature. The probable explanation is that the magnesium silicate of nature generally crystallized from solutions or magmas, the temperature and viscosity of which conditioned the formation of the enstatite or amphibole.

In the foregoing, it has been proved that under atmospheric pressure the monocline pyroxene is the most stable form of magnesium silicate, and it has been shown how various solvents may transform the other polymorphs into this one. Yet it is a very common thing for unstable forms of enantiotropic, as well as monotropic, substances to crystallize first* from solution, whether we start out with a stable or unstable form, provided the solution is not in contact with the stable solid; and in one instance, that of mercuric iodide,† crystals of the unstable yellow variety sometimes form even in the presence of nuclei of the red (stable) form, though they soon pass over into the latter.

We had already found that the unstable amphibole forms from *water* solutions at temperatures of 375°–475°, and it seemed worth while to make the attempt to produce enstatite as well as the orthorhombic amphibole from *silicate* (magmatic) solutions at higher temperature. We used for these experiments portions of 50 to 60 grams, the solutions consisting of magnesium silicate mixed with about 10 per cent of its weight of various other substances. The results are recounted briefly below:

1. 40 grams magnesium silicate and 5 grams of ferric oxide were fused in a Fletcher furnace. The heat was then turned off and the crucible allowed to cool in the covered furnace in which, as the walls are thick, the temperature falls at such a moderate rate that the pure magnesium silicate crystallizes almost entirely in the monoclinic form. A microscopic examination showed that the ferric oxide had not greatly influ enced the crystallization.

* Regarding the crystallization of suphur, see Gmelin-Kraut, Handbuch der Chemie, vol. 1, part 2, p. 155; and for similar facts about phosphorus, see vol. 1, part 2, p. 10. See also O. Lehmann, Molekular-Physik, vol. 1, p. 193, for many other instances of this kind.

† Kastle and Reed, Am. Chem. Journ., xxvii, 217, 1902.

2 42 grams of magnesium silicate and about 4 grams of labradorite (Ab_3An_1) were melted and cooled under similar conditions. The magnesium silicate crystallized chiefly as monoclinic pyroxene with some enstatite present. Small amounts of glass, probably plagioclase glass, filled the interstices between the pyroxene laths.

3. To solution 1, 5 grams of orthoclase were added; the whole was then fused and crystallized as before. This time a quantity of coarsely crystalline enstatite was produced. The orthoclase remained as glass.

4. 50 grams of magnesium silicate and 5 grams of albite were fused and cooled as before. The magnesium silicate crystallized mostly as enstatite, with the characteristic properties: parallel extinction, $c = c$, cleavage prismatic with an angle of about 90°, birefringence not strong, optically positive; 2E apparently larger than usual. The section consisted of clear enstatite laths and intercalated patches of a cryptocrystalline, dust-like aggregate which appears to contain albite and enstatite—perhaps a eutectic mixture of the two. Parts of the aggregate had a refractive index apparently equal to that of albite.

5. 46 grams magnesium silicate, 4 grams sodium metasilicate, and 1 gram potassium metasilicate were fused and cooled under the usual conditions. The cake was filled with beautiful prismatic crystals, the longest of which was 23^{mm} in length. Most of the magnesium silicate had crystallized as enstatite, though there was some of the monoclinic form. The optic axial angle of the enstatite was apparently larger than usual.

6. Preparation No. 4, consisting of the metasilicate with 10 per cent albite, was remelted and cooled more rapidly than the previous solutions. The product consisted chiefly of the low refracting, orthorhombic amphibole form of the metasilicate. Many of the fragments of the product were clearer and showed brighter interference colors than the amphiboles; they consisted of finely intergrown fibers of refractive index slightly less than that of the amphiboles (about 1·560) which may have been due to a solid solution of albite in the amphibole.

7. 4·6 grams of albite were added to 46 grams of the magma described under 6, giving a solution containing about 20 per cent as much albite as silicate of magnesium. The fusion was cooled like 6 and the low refracting amphibole formed. The grains were not clearly transparent and exhibited the dusty appearance observed in the albite-enstatite mixture of product No. 4. The refractive index and other optic properties coincided closely with those of the magnesium amphibole from pure melts.

Silicate solutions can probably be prepared from which the amphibole will crystallize by a process of slow cooling such as prevails in nature, but thus far we have not hit upon a composition which is effective.

In explaining the formation of enstatite in the above cases, the influence of temperature is doubtless of importance. When pure magnesium silicate is cooled slowly enough, i. e., when crystallization occurs at a temperature not too far below the melting point, only the stable monoclinic form is obtained; if cooled more rapidly, enstatite begins to form; still more rapidly, and we have amphibole; and finally, when we chill very suddenly, glass is the result. In all these cases, the temperature at which crystallization occurs is the lower the more rapid the cooling.

The first influence of these solvents is, therefore, no doubt, to lower the temperature at which crystallization takes place, though not all of them are equally effective; the addition of labradorite and ferric oxide makes less difference than albite, orthoclase and the alkaline silicates.

This explanation is, however, an incomplete one, otherwise why should fluxes like the vanadates of magnesium and calcium, tellurous oxide, and magnesium chloride, always give the monoclinic form even at considerably lower temperatures. Comparing these solutions with those which give rise to enstatite, we note at once that the one property which serves to distinguish the two classes is the viscosity. The monoclinic variety is obtained from thinly fluid solutions. At first sight it might appear otherwise with the vanadates, because the whole mass of silicate and vanadate from which we crystallize the silicate seems little more than pasty. The most of the mass is indeed undissolved solid, but the molten vanadates are comparatively thin and so no doubt is the solution which covers the surface of the grains of silicate and colors it yellow. The enstatite, on the other hand, was obtained from solutions which are comparatively viscous at the temperature of crystallization.

The influence which the viscosity of a solvent exerts on the transformation of unstable crystals which stand in contact with it, has been very well shown by Kastle and Reed.* The substance which they investigated was mercuric iodide, an enantiotropic substance with an inversion point at 128°. The yellow form is only stable above this point, yet below that it is always obtained from solutions whatever the solvent may be. The rate at which this form passes over into the red variety, stable at ordinary temperatures, depends on the viscosity of the solvent. Thus with certain mobile solvents like water, the transformation was complete in a very short time, while under a concentrated sugar solution the red appeared only after several days, in glycerine after two weeks, and in vaseline none appeared after a year and a half. In the case of mercuric iodide, so far as known, the unstable form always

* Loc. cit.

crystallizes no matter what the solvent, but this is not true in many other instances. It seems entirely reasonable to expect that if a solvent by its viscosity can hinder a transformation in the solid state, it may also in certain cases restrain the molecules in the act of crystallization from assuming the configuration characteristic of the stablest structure. And we might also expect viscosity to be especially effective where the transformation of the unstable form into the stable is effected with comparative difficulty, as it is in the case of the magnesium silicates. This would explain why enstatite comes out of a viscous silicate solution at a temperature much higher than that at which the monoclinic form is obtained from thinner solutions. At first thought one might be inclined to regard viscosity as directly conditioning the form of the crystal, and to look upon the temperature as merely influencing the viscosity, but further reflection convinces that this can not be so, for we obtained the amphibole from aqueous solutions at 375°–475°. The properties of aqueous solution in general, however, differ widely from others. It is probable that those movements of the molecule which depend directly upon temperature have a very important influence on crystallization. Although temperature and viscosity are certainly important factors in the formation of unstable modifications, the knowledge of the subject is still insufficient, and what we have is too little systematized to generalize in an entirely satisfactory way.

Formation of Amphiboles.—Regarding the formation of forms III and IV, it seems quite beyond the bounds of probability that they should be formed in nature by the rapid cooling, which, on a small scale, is effective. On the other hand, assuming that these forms are really amphiboles, the formation of at least one of them from aqueous solutions, at a temperature of 375°–475°, is consistent with recognized geological forces; at any rate, our experiments indicate that the two amphiboles form at lower temperatures than the pyroxenes. We are inclined to regard the pressure in these experiments as an unessential factor, except in so far as it is necessary to prevent the escape of water at these temperatures, because in the first place it has been seen that both substances (III and IV) could be obtained without pressure, and secondly, the specific volume of these amphiboles, as of all others, for that matter, is greater than that of the corresponding pyroxenes. According to Le Chatelier's principle, pressure should tend to produce the system of smallest volume.

Relation between Pyroxenes and Amphiboles.—Though we refrain from generalizing as yet in regard to the two great mineral groups, the amphiboles and the pyroxenes, we can say that the demonstration of an irreversible (monotropic) relation between each of the two magnesian amphiboles and the stable pyroxenes accords with the experience of many other investi-

gators that, experimentally, amphiboles may be readily changed into pyroxenes but not pyroxenes into amphiboles.

False Equilibria in Nature.—Since these studies have shown the instability of enstatite and the amphiboles of the composition $MgSiO_3$, it may be at once inferred that not all natural minerals are stable. The occurrence of the unstable forms alone constitutes what is commonly called a metastable condition (apparent false equilibrium of Duhem), in which it is generally assumed that equilibrium may be brought about by contact with the stable phase. In another part of this paper it has been demonstrated that such a contact is inadequate, in the case of the magnesium silicates, to determine equilibrium during periods of time which are within the limits of laboratory observation.

Duhem, in his Thermodynamique et Chimie (p. 436), draws a very apt comparison between chemical and mechanical systems. The statics of both are commonly treated as if the systems were frictionless, whereas in both we have to deal with a resistance which in the former is ordinary friction, in the latter an internal friction between the molecules. Chemical systems, in the majority of cases so far studied, seem capable of reaching a true equilibrium, or at least a state which approaches it within measurable limits, but where the systems are composed of viscous liquids or more especially of solids at low temperatures, true equilibrium may not be reached even after an indefinite time, the condition finally attained being not alone the result of molecular forces as conditioned by temperature and pressure, but of these retarding forces which offer an internal resistance of by no means negligible magnitude. (Duhem's genuine false equilibria.) We find in nature false equilibria of this kind, e. g., intergrowths of pyrite and marcasite* among the sulphides, and among the silicates intergrowths of sillimanite and andalusite, and enstatite with monoclinic pyroxene.† It has been generally supposed that the monoclinic pyroxene in the last-named case was a diopside, but our experiments show that similar aggregates form in artificial systems which contain no calcium and that they exist in the Bishopville meteorite. In some cases it is not at all impossible that these systems are in process of very slow change, but there is no optical evidence that this is true of the above-mentioned silicates; in other cases it may be that the two forms were deposited at different times, though in some it would appear that they were actually crystallized together; the important fact to note in them all is that they are systems which are not in equilibrium. Because a rock or mineral aggre-

*Stokes, H. N., U. S. Geol. Survey, Bull. 186.

† We have also obtained intergrowths of the two magnesian amphiboles. Therefore the aggregates of monoclinic and orthorhombic amphiboles in nature probably form another example of this principle.

gate is found in nature, therefore, where it might be supposed to have had sufficient time for attaining equilibrium, is not a sufficient reason for assuming that it has actually reached the state of greatest stability.

Summary.

1. There are four crystal forms of magnesium metasilicate: (I) a monoclinic pyroxene, having the characteristic prismatic cleavage (92° and 88°), and a similar axial ratio $a : b$, but a ratio $c : a$, which varies widely from that of the pyroxenes; (II) an orthorhombic pyroxene identical with enstatite and optically very similar to (I); (III) a monoclinic modification corresponding to an amphibole in its optical properties; (IV) an orthorhombic form, optically also an amphibole and resembling (III) very closely. These forms, with the exception of (III), have been prepared in pure condition or with only traces of other forms; their optical properties have been studied, their specific gravities have been determined, their behavior on heating has been investigated, and, in the case of (I), measurable crystals have been obtained.

Forms (I) and (II) occur in nature, usually in mixed crystals with ferrous silicate, and it is quite probable that the same is true of (III) and (IV).

2. (I) is formed in pure condition by crystallizing a melt a little below the melting point (1521°), which may be readily accomplished by cooling slowly. Measurable crystals are obtained by heating any form of the metasilicate to about 1000° in molten magnesium chloride traversed by a stream of dry hydrochloric acid gas. Calcium vanadate, magnesium vanadate, magnesium tellurite, and other fluxes yield crystals which are not so well developed. All the other forms of magnesium silicate pass into (I) at temperatures between 1150° and 1300°, depending on the crystal form taken. (II). This form (enstatite) crystallizes at lower temperatures than (I); the purest preparation, containing only traces of other forms, is made by heating the glass of the same composition at a temperature between 1000° and 1100°; large crystals of enstatite (up to 23^{mm} in length) were obtained in silicate (magmatic) solutions. (III) forms in very small quantities by rapidly cooling the melt; there is also evidence that it forms from (IV) when the latter is heated with water in a bomb to a temperature of 375°–475°. When an aqueous solution of magnesium-ammonium chloride, or magnesium chloride and sodium bicarbonate is heated with amorphous silica or sodium silicate, this substance is probably formed, though the crystal fibers are too small to decide whether the product is identical with (III) or with (IV). (IV) is obtained by heating the molten silicate high above the melting point, say to 1600°, and then cooling rapidly in air; it cannot be formed by heating the glass.

3. Of the four polymorphic forms of magnesium metasilicate, (I) is the stable form at all temperatures and the others are monotropic toward it, the order of stability being I, II, III, IV. This order is established by changing one form into another at various temperatures and by proving that (II) and (IV) change to (I) with evolution of heat. (III) has not been obtained in sufficient quantity for this test. Though enstatite and the amphiboles are not stable, any more than glasses are, on account of the great internal friction of the molecules, they have less tendency to change, when once formed, than many glasses. We cannot state definite limits of stability for the various minerals, as it is possible to do where the relation is enantiotropic; it is possible, however, to fix certain temperature limits below which one of these forms may crystallize from a melt of pure magnesium silicate. Thus enstatite could only form below about 1250°, since above that temperature it passes into the monoclinic form; but it must be remembered that in the silicate solutions of nature this limit would probably always be lower on account of the general occurrence in them of such compounds as ferrous silicate.

4. The specific gravities of the four forms, in the order of their stability, are: (I) monoclinic pyroxene, 3·192; (II) orthorhombic pyroxene (enstatite), 3·175; (III) monoclinic amphibole, not determined directly, but its relation to (II and (IV) is fixed by its index of refraction; (IV) orthorhombic amphibole, 2·857.

5. While our experiments do not settle completely the mysteries of the formation of unstable bodies, they do show that temperature and viscosity are two factors of prime importance. Thus, from melts or from silicate solutions, the stable monoclinic form of magnesium metasilicate crystallizes at the highest temperature, enstatite next, and the amphiboles probably lowest of all. From *thin solutions* the stable form is obtained at still lower temperatures, 800°–1000°, while from *aqueous solutions* at 375°–475° an amphibole results.

6. Our study of the Bishopville meteorite indicates that it must have been cooled very rapidly from a high initial temperature, and there is evidence that the same is true of other meteorites.

7. The intergrowths of enstatite with the monoclinic pyroxene, and of the two amphiboles, which we obtained in close resemblance to those of nature, are cases of falsee quilibrium, and their occurrence establishes the fact that it cannot be assumed that all rocks or mineral aggregates are systems in true equilibrium.

8. In the course of the investigation a useful method has been developed for detecting sluggish heat changes.

Geophysical Laboratory,
Carnegie Institution of Washington, July, 1906.

ART XXXVIII.—*Contributions to the Geology of New Hampshire: No. II, Petrography of the Belknap Mountains;* by L. V. PIRSSON and H. S. WASHINGTON.

IN a former paper* we presented the results of our studies in the field of the igneous rock masses composing the Belknap Mts. in New Hampshire, and in the present one we purpose to give the results of our investigations of them in the laboratory by microscopic and chemical methods. We have found that the following rocks, classified both in the quantitative and in the older systems, are present:

Class	Order	Rang
Persalane	Britannare	Liparase
Persalane	Britannare	Toscanase
Persalane	Canadare	Pulaskase
Dosalane	Germanare	Monzonase
Salfemane	Gallare	Camptonase

Subrang		Older System
Liparose	(I. 4.1.3)	Aplite
Lassenose	(I. 4.2.4)	Adamellite
Pulaskose	(I. 5.2.3)	Syenite
Akerose	(II. 5.2.4)	Spessartite
Camptonose	(III. 5.3.4)	Essexite and Camptonite

These will be described in the above order and the article will end with a discussion of the petrologic history and of the chemical characters of the district.

Liparase. Aplites.

As previously stated in the foregoing geological description of the district, the Belknap massif and the surrounding metamorphic rocks are cut by dikes and intrusions of fine-grained to dense granitic, quartzose rocks, whose general characters place them under this rang. In Rosenbusch's system of classification they would be aplites, both in the broader and in the more special application of this term. A similar material serves also as the cement of the brecciated zone on Locke's Hill. They have all been studied in thin section, but for purposes of chemical analysis an average type has been selected whose description follows herewith.

Biotitic-grano-liparose (aplite).

Locality.—Dike on upper southwest slope of Mt. Belknap.

Megascopic. — Phanerocrystalline; fine-grained; flesh-colored; persalic and dominantly feldspathic; faintly dotted with

* This Journal, vol. xx, pp. 344–352, 1905.

gray to black specks; apparently equigranular in texture but subporphyritic, with occasional phenocrysts of feldspar 2-3^{mm}; of a sugar granular habit; fracture easy and brittle; superficially slightly weathered.

Microscopic.—Alkalic feldspar and quartz essential; biotite, iron ore, allanite and zircon accessory.

Alkalic feldspars consist of orthoclase and albite in roughly equidimensional anhedral grains. Some albite-oligoclase noted, subtabular to subprismatic in form; albite and Carlsbad twinning. Phenocrystic feldspars roughly equidimensional or cuboidal, of orthoclase with much perthitic intergrowth of soda-microcline and albite. *Quartz*, equidimensional, anhedral, sometimes micrographic with feldspar. Quartz and feldspar of groundmass average 0·5^{mm}. *Biotite* dark brown, pleochroic, tabular, platy and in shreds, subhedral; about 0·2^{mm}, thinly scattered. *Hornblende* very rare, pleochroic, dark green

	I	II	III	IV	V	VI	VII
SiO_2	75·65	76·49	76·05	76·64	76·03	74·12	1·261
Al_2O_3	12·89	11·89	11·68	13·50	11·76	12·39	·126
Fe_2O_3	0·89	1·16	0·34	0·50	1·99	0·31	·006
FeO	1·11	1·56	1·05	n.d.	n.d.	0·21	·015
MgO	0·20	tr.	0·29	0·12	0·27	0·42	·005
CaO	0·48	0·14	0·42	0·65	0·45	0·30	·009
Na_2O	3·71	4·03	3·79	3·48	3·36	3·22	·060
K_2O	5·50	5·00	5·09	5·51	5·61	5·07	·059
H_2O 110°+	0·15	0·12	1·36	n.d.	0·63	2·17	----
H_2O 110°—	0·08	0·38	----	----	----	2·22	----
TiO_2	0·05	tr.	0·05	----	----	----	----
P_2O_5	n.d.	----	----	----	----	----	----
MnO	"	tr.	----	----	----	tr.	----
ZrO_2	"	----	·42	----	----	----	----
	100·71	100·77	100·54	100·40	100·10	100·33	

I. Biotitic-grano-liparose (aplite); dike on upper southwest slope of Mt. Belknap. H. S. Washington analyst.

II. Riebeckite-phyro-liparose (paisanite); Magnolia, Mass. Washington, Jour. Geol., vii, 1899, p. 113.

III. Liparose (quartz porphyry); Drammen, Norway; Lang, Nyt. Mag. xxx, p. 40, 1886; P. Jannasch analyst.

IV. Liparose (granitite); Arild, Kullen, Sweden; A. Hennig, Act. Univ. Lund, xxxiv, 1898. Hennig analyst.

V. Liparose (quartz porphyry); Thal, Thüringerwald, Baden; K. Futterer, Mitth. Bad. Geol. Ld: Anst. II. p. 58, 1893.

VI. Liparose (trachyte); Wantialable Creek, Gowen Co., New South Wales; G. W. Card, Rec. Geol. Surv. N. S. W., iv, p. 116, 1895. Mingaye analyst.

VII. Molecular proportions of No. 1.

and yellow, in shreds or anhedral grains, 0·1 to 0·05^{mm}. *Allanite* rather rare, strongly pleochroic, clear dark brown and orange yellow, zonally built; well crystallized; about 0·1^{mm}; commonly attached to iron ore or biotite. *Zircon* rare, colorless, equidimensional subhedral grains, about 0·2–0·1^{mm}. *Iron ore* uncommon; anhedral; about 0·1^{mm}. Traces of chlorite and kaolin. Fabric porphyritic, but not markedly so, the phenocrysts being rare; remaining grains somewhat grading in size but tending to be equidimensional and interlocked.

Mode.—The chemical analysis and the calculation of the norm show that there cannot be over 4 per cent of iron ores, biotite, hornblende, allanite, zircon, etc., present, the remainder being feldspars and quartz in the proportions indicated in the norm. The mode is therefore normative.

Chemical Composition.—This is shown in No. 1 of the table.

For the sake of comparison a number of analyses of liparose from other localities have been added and it is of interest to observe how these almost identical magmas under varying physical conditions have assumed different textures, so that under systems of classification where texture plays an important part they have been given quite different names and are widely separated in the system. They are all magmas of alkalic nature, as will be shown later.

Norm and Classification.—By using the molecular ratios given in No. VI of the above table we may calculate the norm to be as follows:

Quartz	31·02	Sal = 97·21	$\frac{Sal}{Fem} = \frac{97·2}{3·3} = 29, I,$	Persalane
Orthoclase	32 80			
Albite	31·44			
Anorthite	1·95		$\frac{F}{Q} = \frac{66·19}{31·02} = 2·1, 4,$	Britannare
Diopside	0·46	Fem = 3·31	$\frac{K_2O' + Na_2O'}{CaO'} = \frac{119}{7} = 17, 1,$	Liparase
Hypersthene	1·46			
Magnetite	1·39			
Water, etc.	0·28		$\frac{K_2O'}{Na_2O'} = \frac{59}{60} = 0·98, 3,$	Liparose
Total	100·80			

From the consideration of the analysis and the above norm and by the study of the section it is easily seen that the iron ore, allanite and biotite, are present in negligible amounts and that, as previously stated, the rock has a normative mode. It is therefore normative granophyro-liparose, but if the slightly porphyritic nature which is in no wise characteristic be neglected and the small amount of biotite be taken into con-

sideration this would become biotitic grano-liparose. In the prevailing terminology it would be a granite aplite.

Alkalic character of the rock.—The alkalic nature of rocks, which, like this one, are of high silica content, is to a great extent masked by the large dilution with silica. In a general way we might compare magmas to mixed solutions of salts in water. The ratios of the salts or the oxides which compose them and which give the mixture its general chemical character remain the same whether the compound solution be dilute or concentrated. While the analogy with molten magmas is not exact, since the silica plays a rôle different from water, it will serve in a general way, as the ratios of the metallic oxides are a very characteristic feature. In rocks containing about 55 per cent of silica, the expression of the alkalic nature becomes most evident, so that in speaking of alkalic rocks petrographers are apt to have in mind those which contain about this percentage of silica. Yet rocks with high silica percentages may be as alkalic relatively to the other components as with low. This may be illustrated as follows. Let us take the liparose just described and reduce the silica to

	I.	II.		I*a*.	II*a*.
SiO_2	75·65	55·02	Quartz	31·02	----
Al_2O_3	12·89	23·14	Orthoclase	32·80	58·38
Fe_2O_3	0·89	1·60	Albite	31·44	4·19
FeO	1·11	1·99	Nephelite	----	28·12
MgO	0·20	0·36	Anorthite	1·95	3·89
CaO	0·48	0·86	Diopside	0·46	----
Na_2O	3·71	6·66	Hypersthene	1·46	----
K_2O	5·50	9·87	Olivine	----	2·11
H_2O	0·23	0·41	Magnetite	1·39	2·32
TiO_2	0·05	0·09	Water, etc.	·28	·62
Total	100·71	100·00	Total	100·80	99·63

55 per cent, or in other words, we will subtract 45 per cent of silica from the magma, leave all the other oxides in the original proportions, and reduce the whole to 100. The result is seen in columns I and II of the above table, and their calculated norms, or those minerals which they would naturally form if in a state of dry fusion without the aid of the mineralizers necessary to condition the formation of such alferric minerals as mica and hornblende, are seen in I*a* and II*a*. II and II*a* show the chemical and mineral composition of a characteristic "foyaite," of a somewhat potassic character. To change this to the granite of I it is necessary to dilute it with 82 per cent of its own weight of silica, a figure which shows the great amount of dilution the alkalic magmas of high silica content

suffer, with the consequent masking in large degree of their true character. In the quantitative classification this is obviated to a great extent, for such rocks fall in peralkalic rangs, which fact at once reveals their nature.

At first thought all this may seem merely a rather forceful way of putting well known facts, but the application of it serves to bring out some points in a disputed field. In the endeavor to use the genetic relations of igneous magmas for purposes of classification, it is often implied, if not expressly stated, that we should not expect to find strictly alkalic rocks associated with those of other series, with the granite-diorite or diorite-gabbro families of Rosenbusch, alkalicalcic or docalcic magmas in the new classification. If the idea of alkalic rocks is however broad enough to include those greatly diluted with silica but in which the other oxides are in the proper proportions, as it rightfully should be, then numerous examples which contradict the general supposition mentioned immediately come to mind. Thus in the Yellowstone Park region, as shown by Iddings,* the main lavas extruded have been "rhyolites, andesites and plagioclase basalts," a really typical granito-diorite-gabbro series. An examination of the analyses of these lavas† shows that many of the rhyolites, such as those of Obsidian Cliff, are of highly alkalic nature, belonging in peralkalic rangs which with less dilution by silica would have formed trachytes or phonolites.

Liparase.—The type just described was selected as illustrative of the granitic dikes in the area. There is some variation among them in texture, but so far as one can tell by study of the sections they are certainly peralkalic persalanes and apparently are quardofelic. They fall therefore in liparase and judging by analogy are probably sodipotassic and belong in liparose. This last, however, could not be definitely determined without making chemical analyses, a work whose results would not justify the time and labor. A few words may be added concerning the textural variations of the different occurrences.

Gunstock Dike.—The summit of Mt. Gunstock is cut by a dike three feet wide with the following megascopic characters: phanerocrystalline; inequidimensional; usually porphyritic with medium phenocrysts; pale flesh color; phenocrysts of orthoclase 2–5^{mm}, ill defined, cuboidal to subtabular, scattered; groundmass fine-grained 1^{mm} or less, dotted with minute gray-black specks. Under the microscope the minerals are the same as those mentioned in the type described, including allanite; the groundmass is similar but is thickly crowded with

* Quar. Jour. Geol. Soc., vol. liii, 1896, pp. 606–617.
† Bull. U. S. Geol. Surv., 228, p. 120, 1904.

subhedral phenocrysts of alkali feldspar. The rock is granophyro-liparase or quartz syenite porphyry.

Belknap Dikes and other Occurrences.—On the upper slopes of Mt. Belknap dikes are found of widths varying from a few inches to twenty feet, of branching and anastamosing character. A large one, 20 feet in width, occurs on the shoulder of the west spur of Mt. Gunstock. They are also found as narrow dikelets in the massive rock composing the lower west slopes of Locke's Hill. They are flesh-colored rocks, compact, dense, microcrystalline, showing occasional, scattered phenocrysts of feldspar. Under the microscope they are very fine-grained to almost crypto-crystalline mixtures of quartz and alkali feldspar. In those where the grain is coarser shreds of biotite appear. The feldspar phenocrysts are sometimes of oligoclase but mostly alkalic feldspar and offer nothing of especial interest. In those with the finest grain the material is apt to be arranged in micropoikilitic patches. They are too fine for metric analysis, but their whole character and relations are such that we have placed them provisionally under liparase, though it is possible that sometimes they are quarfelic instead of quardofelic and should be classed as alaskase. In Rosenbusch's system they would probably be termed quartz-bostonites, especially if their relations and genetic associations with the syenite and camptonite be taken into account.

Other instances are found in dikes cutting outward through the enclosing schists at the west foot of Mt. Gunstock. These are fine-grained, megascopically even granular or homometric rocks of pale yellowish to flesh color whose average diameter of grain is about 1^{mm}. They evidently belong under this heading and no further description of them is necessary. In the older systems they would be classed as fine-grained granites or aplites. They stand in evident relation with the pegmatitic masses of quartz and feldspar found in the schists at the head of the Gunstock River.

The Breccia Cement.—As already described in the foregoing part on geology, there is on the lower southwest foot of Locke's Hill a brecciated mass consisting of blocks of various character and of all sizes embedded in a fine-grained aplitic granite intrusion. The study of a number of sections of the latter rock shows that it belongs here in liparase. It is composed of alkalic feldspar and of quartz with occasional larger phenocrystic alkalic feldspars, which are mostly alkalic but sometimes oligoclase. Occasional shreds of biotite, grains of iron ore and zircon occur.

The rock is so like the type analyzed and described and the Gunstock dike that it must be considered as of the same mag-

matic character and probably contemporaneous with them, as will be shown later. In its deficiency of plagioclase feldspar it is unlike the aplitic lassenose (adamellite) of the border facies of the main mass next described, and this fact, which is of importance, will be discussed later.

Biotitic-grano-lassenose (adamellite aplite).

As previously mentioned in the geological part of this paper, the Belknap massif of grano-pulaskose shows on nearly all sides a marginal facies of a light-colored granitic rock into which it gradually passes. Examples of this from various parts of the area have been studied and it has been found to have on the whole a pretty constant composition and character. Its geological occurrence and relationships have been described under the heading of the contact facies of fine-grained granite, using the latter name as a field term.

For purposes of analysis, detailed microscopic study and description, a type specimen was selected from the south end of Piper Mountain, where it is exposed in a cliff near the high road running through the notch to Young's Pond.

Megascopic.—Phanerocrystalline; fine-grained; light brownish gray; dominantly quartzo-feldspathic but dotted with minute specks of black biotite and shining white muscovite; of an even granular texture with sugar granular habit and feel; distinctly gneissoid and with perceptible eutaxitic structure; of an easy fracture and rather friable.

Microscopic.—Alkalic feldspar, andesine and quartz essential, biotite and muscovite accessory. Essential minerals present in approximately equal amounts. Average size of grain 0·2^{mm}: occasional individuals much larger but not phenocrystic; some smaller. *Alkalic feldspar*, OrAb, equidimensional anhedral. *Andesine*, Ab_3An_2, equidimensional anhedral to subtabular or subprismatic; albite twinning common, Carlsbad not common, pericline rare. *Quartz* equidimensional anhedral, often spheroidal. *Biotite* brown with not intense pleochroism, in form tabular to scaly. *Muscovite* tabular and scaly.

Mode.—For the determination by Rosiwal's method of the relative amounts of minerals making up the rock, 150 measurements were made in a distance of 3000 units. The average size of grain was 0·2^{mm}. Reduced from volumes to percentages by weight this gave:

Quartz	33·50
Orthoclase	30·86
Andesine (Ab_3An_2)	31·04
Biotite	3·77
Muscovite	·83
	100·00

If we neglect the small amount of K_2O which is in the micas and consider all of the lime and alkalies shown by the analysis as in feldspar, the total weight of the latter thus calculated would be 60·15 per cent while the above by measurement gives 61·90 per cent. The andesine was determined as Ab_5An_3 by a number of measurements. If we take the amount of lime shown by the analysis and convert it into Ab_5An_3 it gives 34·30 per cent and the amount of soda-orthoclase remaining would be 25·85, which is not a bad agreement with that obtained from the measured areas, especially if one takes into account the fact that some of the untwinned areas of andesine are liable to be measured as orthoclase.

Chemical Composition.—This is shown in the following analysis, No. 1 of the table:

	I	II	III	IV	V
SiO_2	69·76	69·70	69·43	68·11	1·163
Al_2O_3	18·22	18·72	15·74	15·80	·178
Fe_2O_3	0·25	0·65	0·93	1·97	·002
FeO	1·59	0·79	3·35	1·87	·022
MgO	0·40	0·45	1·35	0·96	·010
CaO	2·68	2·25	2·07	2·43	·048
Na_2O	4·06	5·01	4·56	4·40	·066
K_2O	2·06	1·68	2·99	2·80	·022
H_2O 110°+	0·50	0·71	·10	0·54	----
H_2O 110°—	0·15	----	----	·16	----
CO_2	none	----	----	x= ·75	----
TiO_2	0·36	----	----	.07	·005
Total	100·03	99·96	100·52	99·87	

I. Biotitic grano-lassenose (granite-diorite-aplite?). South end of Piper Mt., Belknap Mts., N. H. H. S. Washington analyst.

II. Lassenose (quartz porphyry); Kawishiwi River, Minnesota (Grant, An. Rep. Geol. Nat. His. Surv. Minn., p. 43, 1893). A. D. Meeds analyst.

III. Lassenose (andengranit); Juncal Valley, Argentina (Stelzner, Btr. Geol. Arg. Rep. I, p. 208, 1885). H. Schlapp analyst.

IV. Lassenose (granite); Mühlberg, Odenwald, Hesse (Chelius, N. J. 1884, II, p. 419, x = P_2O_5 0·62; SO_3 0·13).

V. Molecular ratios of No. I.

While some of the combined water shown by the analysis is of course in the micas, the amount seems too large for the percentage of these minerals present. The high alumina, which as seen in the calculation of the norm cannot all be referred to feldspar, is also too great for them and the micas. This might indicate some kaolin, but the rock appears remarkably fresh under the microscope and kaolin is absent. It is difficult to know to what to attribute the high alumina. Nothing seen in

the section exactly explains it, and the analyst is confident that it is not to be attributed to admixture of magnesia.

In comparing the composition of this rock with similar ones, as seen in the table, the predominance of soda over potash, producing as it does an amount of plagioclase equal to the alkalic feldspar, causes a certain difficulty, if one pays attention to the older systems of classification. This may be seen by referring to the analyses included under the subrang of lassenose in the tables of analyses recently published by one of us.* One sees under this subrang, which includes rocks of a similar chemical composition, types which have been called granites, syenites and quartz diorites, as well as rhyolites, dacites, andesites and trachytes, indicating the middle position which such a magma holds.

Classification.—In the quantitative system the norm of the rock calculated from the molecular ratios is as follows:

Qz	30·72	30·72			
Or	12·23				
Ab	34·58	60·15	95·15	$\frac{Sal}{Fem} = \frac{95·15}{4·20} = 22·6$	Persalane, 1
An	13·34				
Co	4·28	4·28		$\frac{Q}{F} = \frac{30·72}{60·15} = 0·51,$	Britannare, 4
Hy	2·98				
Mt	·46	4·20	4·20	$\frac{K_2O' + Na_2O}{CaO} = \frac{88}{48} = 1·8,$	Toscanare, 2
Il	·76				
H_2O	·65			$\frac{K_2O'}{Na_2O'} = \frac{22}{66} = 0·33,$	Lassenose, 4
Total,	100·00			Place formula, I, 4, 2, 4.	

The extra alumina above that needed to produce feldspars is shown above by the production of 4·28 per cent of corundum among the normative minerals. The texture is granular, the micas are not present in notable amount and the mode is therefore normative. If it is desired to note the small amount of biotite present the rock is therefore a biotitic-grano-lassenose.

In the prevailing qualitative systems it is somewhat difficult to place this rock. It is a marginal facies of a syenite mass with aplitic habit showing some fluidal structure, and it stands mineralogically exactly on the line between the granite and diorite families. If we determined it as an aplite from its minerals and texture and used Brögger's definition of the monzonite family, it would be a quartz monzonite aplite or adamellite aplite.† Or it might be called a grano-diorite aplite, using grano-diorite, as many have done, to signify a transition rock between the granite and diorite families.

* Chem. Anal. Ign. Rocks, U. S. Geol. Surv., Prof. Paper 14, 1903, p. 173.
† Brögger, Predazzo. Vid. Selsk. Skrift. M-N. Kl. 1895, No. 7, p. 60.

Inclusions in Lassenose.—In the border facies of the mass are to be seen, as noted by Hitchcock, dark inclusions or schlieren of variable size. Sometimes these are angular and of definite shape. Under the microscope they show the characteristic minerals, such as quartz, brown mica, iron ore, etc., and the fabric seen in certain hornfels, and are no doubt fragments of schists, etc. caught up and metamorphosed by the magma. In other cases, as in the occurrences on the slopes above Point Belknap, they may have no definite form but are streaks and smears through the rock. The study of them in thin section reveals a type of rock closely allied to monzonase, monzonites in the current nomenclature. They are composed of a colorless to pale green pyroxene, green hornblende and brown biotite, labradorite and alkalic feldspar with accessory iron ore, apatite, etc. The labradorite is in stout laths which serve as cores for irregular ragged masses of feldspar, the plagioclase core passing outwardly into alkalic feldspar mantles. Broad areas of the soda orthoclase also occur poikilitically enclosing other minerals. The amount of the ferromagnesian minerals, though variable from place to place in kind, is in amount nearly equal to the feldspathic. The masses in fact closely recall types from Monzoni and Yogo Peak, Montana. They are believed to be of magmatic and not of foreign origin, and the study of the brecciated zone on the west side of Locke's Hill, as described elsewhere, throws light on their origin.

Hornblendic-grano-pulaskose (syenite).

This is by far the most important rock in the area from the geologic point of view, as it forms the major part of the great massif. A certain type of it appears to be rather uniform over the exposed area, although minor variations which will be described occur from place to place. For purposes of chemical and microscopical analysis and study a representative specimen was selected from a ravine on the west slope of Mt. Belknap about a third of the way from Morrill's farm house to the top of the peak.

Megascopic. — Phanerocrystalline; medium to coarse-grained; pale reddish, white to gray; dominantly feldspathic but sparsely dotted with anhedra of black hornblende and of biotite; of a granular to subporphyritic fabric; feldspars mostly equidimensional, occasionally larger than the average and subtabular to prismatic; fracture rather crumbly; superficially somewhat altered.

Microscopic.—Alkalic feldspar and hornblende essential; biotite, iron ore, apatite, oligoclase-andesine, quartz and zircon accessory.

The *feldspars* consist of orthoclase with microperthite intergrowths of soda microcline. In a section perpendicular to c and nearly parallel to *b* (010), oriented by the good cleavage of *c* (001) and rough parting parallel to *m* (110) and by the arrangements of inclusions giving the direction of the vertical axis and a measured angle for β of 64°, the main feldspar extinguished at 7° from the trace of the base *c*, that of the microperthite intergrowths at 11° in the obtuse angle β'. Thus the main crystal is of orthoclase, the intergrowths of soda-microcline (anorthoclase). The amount of these intergrowths is very large, indeed in most cases they appear to be as great as, or even greater in volume than, that of the host crystal. Sometimes these intergrowths show distinct multiple twinning and the optical properties prove them to be of oligoclase-andesine (Ab_2An_1). Feldspars enclose all the other minerals save quartz. They are in formless masses, at times having poor tabular development, with Carlsbad twinning common. No microcline was observed, and the feldspars are somewhat kaolinized.

The *hornblende* is in anhedral masses, at times poorly developed as short columns. Prismatic cleavage is good. It is strongly pleochroic: c, olive-green to deep green; b, olive-brown; a, pale brown; absorption medium strong, c>b>a. Angle of *c* on c = 18°–20°. From these properties it is probably a mixture of the common hornblende and barkevikite molecules. It rarely contains a paler green core, and includes iron ore, zircon, apatite and biotite. In some places it is altering into a reddish substance, probably göthite. The rock at the summit of Gunstock contains 13·4 per cent of hornblende; the type analyzed has somewhat less, probably not over 8 per cent.

Biotite is quite subordinate in amount, while in other varieties of the massif it becomes more abundant, increasing with the amount of quartz, and in the marginal facies, which are rich in the latter mineral, it entirely replaces hornblende. It is of the type of common biotite, brown, strongly pleochroic, with inclusions of iron ore, apatite and zircon and with pleochroic halos. It is older than hornblende and automorphic against it, and quite unaltered. *Iron ore* occurs in occasional scattered grains. *Zircon* is present in crystals varying from excessively minute microlites to some of good size, rather common and sowed through all the later minerals. It is well crystallized with *m* (110) and *p* (111) well developed. *Apatite* is also common in slender microlites and larger stout prisms.

Quartz is seen in very small amount in the type specimen in small xenomorphic masses, serving as a cement between the other minerals. It is too rare to characterize the rock as quartz-bearing. In a variety on the top of the hill beside the road from Gilford to West Alton it is entirely lacking in two thin

sections. In the lassenose marginal facies of the massif, as noted above, it becomes quite abundant.

In addition to the above, two or three small sections of an indeterminable brown mineral were noted. It is strongly pleochroic, varying from a clear chestnut brown to practically opaque, like ænigmatite. The refractive index is about that of hornblende; birefringence not high, but as the sections are cut nearly perpendicular to an optic axis whose bar crosses the field, in conjunction with the deep absorption, this cannot be well told, nor can any other optic characters be determined. The bar crosses the field without apparent bending, but it is not certain that the mineral is uniaxial. The color is unusual for tourmaline, the absorption too strong for cassiterite; if biaxial the color and absorption much deeper than ordinarily seen in allanite and much like that of ænigmatite, but the mineral associations scarcely suggest the latter. It seems most probable that it is an unusually deep-colored allanite.

ANALYSES OF PULASKOSE, ETC.

	I	II	III	IV	V	VI
SiO_2	60·75	60·20	65·54	63·71	63·20	1·013
Al_2O_3	19·68	20·40	17·81	18·30	17·45	·193
Fe_2O_3	1·54	1·74	0·74	2·08	3·60	·010
FeO	2·98	1·88	1·15	2·52	n. d.	·041
MgO	0·81	1·04	0·98	0·09	0·75	·020
CaO	2·29	2·00	1·92	1·18	1·40	·041
Na_2O	4·89	6·30	5·55	6·39	6·90	·079
K_2O	5·90	6·07	5·58	6·21	5·88	·063
H_2O 110°+	0·08	0·23	0·54	0·17	0·50	----
H_2O 110°—	0·24	0·10	----	0·09	----	----
CO_2	----	none	----	----	----	----
TiO_2	0·63	0·14	0·11	tr.	0·46	·008
P_2O_5	tr.	0·15	tr.	----	----	----
SO_3	----	0·13	----	----	----	----
Cl	----	0·09	----	----	----	----
MnO	tr.	tr.	tr.	tr.	----	----
Total	99·79	100·47	99·92	100·74	100·14	

I. Pulaskose (syenite). West slope of Mt. Belknap, N. H. Washington analyst.

II. Pulaskose (pulaskite). Fourche Mountain, near Little Rock, Arkansas. Washington analyst (Jour. Geol. ix, 1901, p. 609).

III. Pulaskose (syenite). Highwood Peak, Highwood Mts., Montana. Pirsson and Mitchell analysts. (This Jour. i, 1896, p. 295.)

IV. Phlegrose (pulaskite). Salem Neck, Essex Co., Mass. Washington analyst. (Jour. Geol. vi, 1898, p. 806.)

V. Nordmarkose (nordmarkite). Tönsenas, near Christiania, Norway. G. Forsberg analyst. (Brögger, Zeitschr. Kryst. xvi, 1890, p. 54.)

VI. Molecular ratios of No. I.

Mode.—The rock is too coarse-grained to determine the actual mineral composition on ordinary sections by the Rosiwal method with any degree of accuracy, but from measurements made on the hand specimen with a millimeter scale it appears that about 10 per cent of alferric minerals, chiefly hornblende, are present, the remainder being alkalic feldspar with a little quartz.

Chemical Composition.—The analysis of the specimen gave the result shown in No. I of the foregoing table:

The very small amount of water yielded in the analysis proves that the rock is really in a very fresh and unaltered condition and that the pink color and slight staining are quite superficial.

For comparison two other analyses of pulaskose are added, one the typical rock from Arkansas and one described by one of us from Montana, and also a phlegrose from Massachusetts. In some ways the rock is closely related to nordmarkose from Norway and the analyses are not very different. The greater amount of lime in the Belknap rock throws it in the domalkalic rang and the larger relative amount of potash compared with the soda into the sodipotassic subrang, nordmarkose being peralkalic and dosodic.

Classification.—In the quantitative system the norm is calculated to be:

Quartz	2·04	90·88	$\frac{Sal}{Fem} = \frac{90·88}{8·61} = 10·05$, I, Persalane
Orthoclase	35·03		
Albite	41·39		
Anorthite	11·40		$\frac{Q}{F} = \frac{2·04}{87·82} = 0·02$, 5, Canadare
Corundum	1·02		
Hypersthene	5·30	8·61	$\frac{K_2O' + Na_2O'}{CaO'} = \frac{142}{41} = 3·4$, 2, Pulaskase
Magnetite	2·09		
Ilmenite	1·22		$\frac{K_2O'}{Na_2O'} = \frac{63}{79} = 0·8$, 3, Pulaskose
Water	32		(I, 5, 2, 3.)
Total	99·81		

From this table and from what has been stated regarding the fabric and component minerals, the rock should be termed a normative-hornblendic grano-pulaskose.

The lime-alumina molecules which form anorthite in the norm are divided between the oligoclase-andesine and hornblende of the mode, but the latter of these minerals is not present in sufficient amount to render the mode abnormative. In the prevailing qualitative systems the rock would be a typical syenite and would belong to the Albany type of Rosenbusch.

Variations from the type.—The rock described may be assumed to be about the average of the Belknap massif, as it agrees with the microscopic examination of most of the specimens. Indeed all of them are obviously of the perfelic order and of the sodipotassic subrang. While most of the material undoubtedly belongs to the persalane class there is a distinct tendency in some to be dosalic, through increasing content in alferric minerals. Similarly labradorite appears and may be present in variable amount so that the rang will vary from peralkalic to domalkalic, the latter being the more common as in the type specimen.

In order to test the amount of variation which, as stated in the geologic description, appears to take place chiefly as the outer border is approached, the mode of two other specimens was determined by Rosiwal's method with the results given below. Of these No. I is from the exposure in a ravine in the little drainage on the south west side of Locke's Hill and not far from the contact. No. II is from the very summit of Gunstock peak.

Mode.		
	I.	II.
Qz	16·06	4·25
Or	72·31	67·95
Ab_3An_1	0·00	2·53
Hb	0·35	13·38
Bt	9·93	7·59
Mt	1·15	3·82
Ap	0·20	0·48
Total	100·0	100·00

Chem. composition.		
	I.	II.
SiO_2	68·16	59·91
Al_2O_3	15·27	15·82
Fe_2O_3	0·88	2·93
FeO	1·87	4·61
MgO	1·26	1·64
CaO	0·15	1·92
Na_2O	4·30	4·52
K_2O	7·06	6·61
H_2O	0·37	0·43
TiO_2	0·59	1·39
P_2O_5	0·09	0·22
	100·00	100·00

Mol. ratios.		
	I.	II.
	1·106	·998
	·150	·155
	·006	·018
	·026	·064
	·032	·041
	·003	·034
	·069	·073
	·075	·070
	·007	·018
	·001	·002

Norms.		
	I.	II.
Qz	13·62	1·86
Co	0·61	----
Or	41·70	38·92
Ab	36·15	38·25
An	----	3·34
Di	----	3·65
Hy	4·93	6·00
Mt	1·39	4·18
Il	1·06	2·74
Ap	0·24	0·50
H_2O	0·37	0·43
	100·06	99·87

From this No. I is I, 4, 1, 3 = liparose and No. II is II, 5, 1, 3, = ilmenose. While these two norms are not entitled to quite the weight of that derived from the chemical analysis, yet, as the modes were determined on sections of large size ($50x40^{mm}$, rock surface) and from a very large number of measurements, a fair degree of confidence may be placed in them.* Suitable compositions were assumed for the hornblende and biotite in working out the chemical composition, and since their amounts are not large the error in this direction must be inconsiderable. Assuming this, it is evident that considerable variation exists in the outer exposed portion of the Belknap massif, especially in regard to the amount of alferric minerals, determining the class, the amount of quartz determining the order, and that of lime which determines the rang.

It is to be noted that the rock from Locke's Hill is from near the contact, and on this account, as seen in its high silica content, it is to be regarded as homologous with the siliceous border facies which has been already mentioned in the geological description, though it differs from this texturally in being much coarser-grained.

On the other hand, the rock from the summit of Gunstock may reasonably be supposed to represent a more central part of the mass of magma than the specimen analyzed, which came from a spot presumably much nearer the border. There is thus a successive decrease in alferric minerals with an increase in quartz from center to circumference. This is more fully treated in another place.

In a specimen from the top of Piper Mountain which is megascopically similar to that from Gunstock, the section showed the presence of a colorless diopside associated with the hornblende and more or less intergrown with it. Some oligoclase also appears and these minerals, as will be shown later, point to a small increase in lime in the massif towards the south end. Otherwise the rock is similar to that from the summit of Gunstock.

Hornblende-trachi-akerose (*spessartite*).

As previously stated, the brecciated intrusive zone at the west foot of Locke's Hill contains in an aplitic liparase cement blocks of various rocks brought up by the ascending magma. Some of these are clearly masses of the gneisses and schists, some are of the Gilfordal camptonose (essexite), while some are of a dense lamprophyric type. It was thought that a detailed study of one of these latter would be of interest and might

* It is probable that the orthoclase is somewhat sodic, so that the K_2O is rather too high and the Na_2O too low, but to what extent is uncertain.

shed some light on the sequence of magmatic eruptions in the area, and a specimen was selected from a large angular block several feet in diameter embedded in the liparase.

Megascopic.—Phanerocrystalline; fine-grained, too dense for the individual minerals to be recognized but perceptibly granular; very dark stone gray, almost black; tough with hackly fracture. Rare, very inconspicuous, equidimensional, dull hornblende phenocrysts 0·5–1·0^{mm}. Speckled here and there with small grains, streaks and minute veinlets of pink feldspar and quartz, the grains sometimes 2–3^{mm} with feldspar cleavage and of ragged, broken or irregular contours, evidently included or injected material and not normal phenocrysts.

Microscopic.—The section shows iron ore, apatite, hornblende, plagioclase, alkalic feldspar and quartz.

The iron ore occurs in two forms; as scattered grains, somewhat rounded, about 0·02–0·05^{mm}, and as minute spheres, ovoids and rods about 0·001^{mm}, sprinkled through all the minerals and especially the feldspar, where they are often aligned into small systems. They distinctly suggested the iron ores seen in contact hornstones.

Apatite occurs in excessively minute needles in the feldspars. Hornblende is of a green color, strongly pleochroic into tones of pale yellow; it includes occasional grains of iron ore and some pieces have the central part blackened by separated iron ore dust and needles much like those which in lavas have suffered partial resorption. It is in irregular forms with a tendency to columnar development. Occasional flakes of biotite are sometimes associated with it.

The plagioclase is zonally developed with the customary more calcic cores and passing to alkalic feldspar mantles. It shows both albite and Carlsbad twinning, but much is untwinned and distinguished from alkalic feldspar only by its zonal development. The cores are of labradorite, the outer portion passing into andesine. It has a somewhat columnar development parallel to the *a* axis, but like the hornblende the boundaries are irregular.

The alkalic feldspars are similar in form to the plagioclase and are not always easily distinguised from them when untwinned. From the analysis it must be concluded that they are very rich in soda.

The small spots and streaks mentioned above are irregular fragments of alkalic, rarely plagioclase feldspar, often much filled with sericitic muscovite sometimes accompanied by quartz. They are clearly exotic, included or injected material, and do not belong to the rock proper.

Mineral Composition or Mode.—By Rosiwal's method the rock was measured and calculated to have the following composition:

Alkalic feldspar	20·0
Plagioclase feldspar	27·2
Hornblende	35·3
Biotite	0·9
Iron ore	14·8
Apatite	1·7
Total	99·9

In obtaining this a part of the rock was selected free from inclusions to give the normal composition. On account of their characters the feldspars could not be accurately discriminated and the two were measured together and their relative amounts then estimated, the result being checked by the alkalies shown in the analysis. Thus while their total amount relative to the other minerals is nearly correct, their proportions to each other are only approximate. The small grains of iron ore in the feldspars could not be measured and a small amount was deducted for them and added to the measured ore areas. The apatite also could not be measured but is obtained from the

	I.	II.	III.	IV.
SiO_2	52·95	50·97	52·85	·883
Al_2O_3	14·96	15·56	13·25	·147
Fe_2O_3	2·44	4·43	2·36	·015
FeO	7·03	7·62	8·71	·097
MgO	3·86	4·28	6·84	·097
CaO	6·76	7·05	8·47	·121
Na_2O	4·95	5·04	4·72	·080
K_2O	1·64	1·26	1·53	·017
H_2O 110°+	0·55	1·58	0·93	----
H_2O 110°—	0·09		----	----
CO_2	0·00	----	----	----
TiO_2	3·90	1·98	0·35	·049
P_2O_5	0·76	0·43	0·40	·005
S	0·05	0·16	----	----
ZrO_2	0·02	----	----	----
MnO	trace	0·38	----	----
BaO	0·00	----	----	----
Total	100·16	100·74	100·41	

I. Hornblende-akerose (spessartite). Belknap Mts., N. H. Washington analyst.

II. Augite-andose (augite kersantite). Cordillera de Doña Ana, Coquimbo, Chile. (F. v. Wolff, Zeitschr. d. deut. Geol. Ges., li, 1899, 529) ; Soenderop analyst.

III. Hypersthene-kilauose (basalt). Cerro San Miguel, Puebla, Mexico. (Felix and Lenk, Beitr. Geol. Mex., ii, 1899, p. 215). Hoppe analyst.

IV. Molecular ratios of No. I.

P_2O_5 of the analysis. With these corrections the composition is as stated above and it must be reasonably correct.

Chemical Composition.—This is shown in the analysis given below and it will be seen that the rock has the usual characters of a lamprophyre. The most notable feature is the predominance of soda over potash. The rock most nearly related to this one, both in magma composition and in geologic occurrence, of which we have found an account in the literature, is one from Chile given in No. II, while another of similar composition from Mexico is given in III. It should be remarked here that the analysis (I) probably does not represent quite accurately the composition of the pure normal rock, since the small included fragments of feldspar and quartz previously mentioned were unavoidably present to a limited extent. Their influence must be very minute, but the silica, alumina and alkalies are a trifle too high on that account.

Texture.—The average grain of the rock is about 0·05^{mm} and the hornblendes and feldspars approximate quite closely to this and do not vary much in size. The fabric is that commonly seen in rocks of lamprophyric character, and which Rosenbusch has designated as "panidiomorphic granular" in which the constituents appear of equal age, interlock with one another and yet have a distinct tendency to a columnar form. This fabric, however, is not clean cut and clear, as one often sees it, for the hornblendes are somewhat rounded, as are the ore grains, and the feldspars are irregular in outline and everywhere dotted with the little spheroids and rods of iron ore. Thus in plain light there is a distinct impression of the hornfels fabric with its rounded grains and dots, but when the nicols are crossed this disappears and the normal fabric is revealed. This is of interest because it shows that the original fabric has been affected to some extent by the immersion of the blocks in the liparase magma, and further evidence is seen in the separation of the iron ore in the hornblendes and in the sericitic mica in the large feldspars previously described.

Classification.—In the quantitative system the calculation of the norm of the rock and its position are given below.

Qz	0·96	66·23
Or	9·45	
Ab	41·92	
An	13·90	
Di	12·33	
Hy	8·11	
Il	7·45	33·05
Mt	3·48	
Ap	1·68	
Rest	0·71	
Total	99·99	

$$\frac{Sal}{Fem} = \frac{66{\cdot}23}{33{\cdot}05} = 2 = II, \text{ Dosalane}$$

$$\frac{Q}{F} = \frac{1}{65} = 0{\cdot}01 + 5, \text{ Germanare}$$

$$\frac{K_2O' + Na_2O'}{CaO'} = \frac{97}{50} = 1{\cdot}94 = 2, \text{ Monzonase}$$

$$\frac{K_2O'}{Na_2O'} = \frac{17}{80} = 0{\cdot}21 = 4, \text{ Akerose}$$

The texture cannot be very well described in one word; it approaches roughly to the trachytic; but is not porphyritic. The mode on account of the large amount of hornblende is abnormative and thus the rock is a hornblende-trachi-akerose.

In Rosenbusch's system of classification the rock belongs in the vogesite-odinite series of lamprophyres and corresponds in general with the spessartite of this group; the hornblende is, however, not brown but common green and the considerable quantity of alkalic feldspar shows relations to the vogesites in which this mineral dominates the plagioclase feldspars.

Mt. Belknap Dike.—A rock which is practically the same as that just described forms a dike, six feet in width, which cuts the top of Mt. Belknap with an east and west trend. It differs in that it contains numerous phenocrysts of labradorite with tabular development, $0{\cdot}5^{mm}$ long by $0{\cdot}1^{mm}$ broad on the average, which are quite thickly sprinkled through the dark gray groundmass. The latter in thin section is similar to the type just described, without however the suggestion of the hornfels texture.

It may be also noted here that the above rocks mineralogically are quite similar to certain facies of the grano-camptonose (essexite) mass in which the latter passes locally into a monzonose (monzonite) phase. They differ of course texturally and they do not contain so much biotite, but the relation is a significant one for the explanation of the origin of these dikes, as will be mentioned later.

[To be continued.]

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Preparation of Pure Ethyl Alcohol and Some of its Properties.*—Since commercial absolute alcohol contains one or two per cent of water, and is usually contaminated also with aldehyde, L. W. Winkler has worked out a method for purifying it, and has incidentally determined the specific gravity and boiling point of the pure substance. The aldehyde is first removed by adding very finely divided silver oxide and allowing it to act for several days with frequent shaking at ordinary temperature. At the same time, a little caustic alkali is added to combine with the acetic acid produced by the oxidation of the aldehyde. For dehydration, metallic calcium in the form of filings is used. An amount of this metal corresponding to about two per cent of the alcohol is added in the distilling flask, and a gentle heat is applied, so that little alcohol distils over, until the evolution of hydrogen is slight. Distillation then gives a product containing about 99·9 per cent of alcohol, and this when redistilled with about one-half per cent of calcium gives alcohol which is unchanged in specific gravity by further treatment. It is important that a small portion of each distillate coming over at first should be discarded. Specific gravity determinations of alcohol purified in this way gave results practically identical with those of Mendeléeff between 0° and 15°, but between 15° and 30° they were slightly lower than Mendeléeff's. The results gave the following formula based upon weights *in vacuo* and water at 4° :

$$\text{Sp. gr. } 0-30^\circ = \cdot 80629 - \cdot 000838t - \cdot 0000004t^2.$$

The boiling point was found to be 78·37° at 760^{mm} and 77·69° at 740^{mm}, the variation for 1^{mm} being ·034°.—*Berichte*, xxxviii, 3612. H. L. W.

2. *Double Salts of Mercuric Chloride with the Alkali Chlorides.*—In continuation of similar work previously carried out in the Sheffield Laboratory by Professor H. W. Foote, Foote and Levy have studied the sodium-mercuric, potassium-mercuric and rubidium-mercuric chlorides by the solubility method, which shows very precisely and conveniently all the double salts that are formed at a given temperature. The results show that only one sodium salt, $NaCl.HgCl_2.2H_2O$ is formed at 25° and at 10°. Three potassium salts, all of which had been described by Bonsdorf, were found :

$$2KCl.\ HgCl_2.\ H_2O$$
$$KCl.\ HgCl_2.\ H_2O$$
$$KCl.2HgCl_2.2H_2O$$

Five different rubidium compounds were prepared, none of which corresponded to three supposed salts previously described by Godeffroy. They have the following formulæ :

$2RbCl.\ HgCl_2.\ H_2O$
$3RbCl.2HgCl_2.2H_2O$
$RbCl.\ HgCl_2.\ H_2O$
$3RbCl.4HgCl_2.\ H_2O$
$RbCl.5HgCl_2.$

It is interesting to observe that only the last member of this series corresponds to one of the five cæsium-mercuric chlorides that exist, viz.:

$3CsCl.\ HgCl_2$
$2CsCl.\ HgCl_2$
$CsCl.\ HgCl_2$
$CsCl.2HgCl_2$
$CsCl.5HgCl_2.$

There are two corresponding salts in the potassium and rubidium series, but the slight analogy existing between double salts of such closely related metals as cæsium and rubidium is remarkable. —*Amer. Chem. Jour.*, xxxv, 236. H. L. W.

3. *The Atomic Weight of Tantalum.*—The accepted atomic weight of this element, 183, depends solely upon Marignac's results obtained in 1865 by analyses of the compound K_2TaF_7. Since these results are subject to some uncertainty from various causes, Hinrichsen and Sahlbom have made some new determinations of this atomic weight. They were unable to obtain concordant results by the method of Marignac, but they had, apparently, better success by determining the weight of Ta_2O_5 produced by heating the metal in oxygen. The metal was obtained from Siemens and Halske, who now prepare it for commercial purposes, and no impurities could be found in the material used. The results of five determinations made in this way indicate an atomic weight of 181, which is two units lower than the accepted one. The results varied from 180·59 to 181·77. It may be mentioned that this atomic weight adapts itself to Mendeleéff's periodic system somewhat better than the old one, since it is three units lower than tungsten, 184.—*Berichte*, xxxix, 2600. H. L. W.

4. *The Isomorphism of Northupite and Tychite.*—The octahedral mineral tychite, $2MgCO_3.2Na_2CO_3.Na_2SO_4$, was described by Penfield and Jamieson in this Journal of September, 1905, having been found among exactly similar crystals of northupite, $2MgCO_3.2Na_2CO_3.2NaCl$, from Borax Lake in California. In connection with the description of tychite, its artificial preparation was also carried out. A. de Schulten, who had previously prepared northupite artificially, has now succeeded in making crops of crystals which appear to contain both chloride and sulphate in the same individuals, thus indicating that the two compounds are perfectly isomorphous. He finds that the tychite is much more stable than the northupite.—*Comptes Rendus*, clxiii, 403. H. L. W.

5. *Separation of Antimony and Tin.* — A new method for this somewhat difficult separation is given by A. CZERWEK. It depends upon obtaining a solution in nitric and tartaric acids, heating to boiling and adding phosphoric acid, whereby the tin is completely precipitated. The precipitate, after being washed with water containing ammonium nitrate, is dissolved in ammonium sulphide, and the tin is precipitated and determined in the usual manner. The antimony and other metals that the filtrate may contain must also be precipitated as sulphides in order to separate them from the phosphoric acid present. Satisfactory results are given in a number of test analyses.—*Zeitschr. Analyt. Chem.*, xlv, 505. H. L. W.

6. *Lehrbuch der Allgemeinen Chemie;* by Dr. W. OSTWALD. Volume II, Part III.—The third part of Volume II of the Lehrbuch has appeared in sections, and we have just received the first part of the second section. The book is so divided into volumes and parts and sections that it is a little confusing in this respect. The work is so well known to students of general chemistry that it is unnecessary to speak of it as a whole. The part which has just been issued covers solid solutions more fully than this has been done before and begins the chapter on adsorption.

H. W. F.

7. *Radio-activity.* — The literature of this subject increases very rapidly. Apart from the numerous observations on the various forms of radio-active substances and their multifarious manifestations, there are certain aspects of radio-activity which have a broad bearing upon the constitution of the sun and the radio-active constitution of this earth and its atmosphere. A recent paper on the radio-activity of the ashes and lava thrown up by the late eruption of Vesuvius (August Becker, Ann. der Physik, No. 8, 1906) is of much interest. Since it has been shown by various observers that radio-activity is widely present in the earth's crust, the question has arisen, whether it would not be possible to connect the phenomena of radio-activity with the earth's temperature? Under the assumption of a mean value of 0·006 for the heat conduction of the earth's crust, and a temperature fall of 1° C. for 30 meters, Liebenow estimates the quantity of radium per cubic meter evenly distributed, which would give the observed heat as approximately 2×10^{-7}g. Since the quantity of radium observed is 1000 times this, we must conclude that the heat production diminishes rapidly as we recede from the crust and that at great depths there cannot be radio-active substances. Strutt corroborates the results of Liebenow and concludes that at a depth of 75^{km} radio-activity fails. BECKER, therefore, submitted to test the ashes and lava of the eruption of Vesuvius, and corroborates in general the observations and conclusions of Strutt, pointing out, however, that we are unable to estimate conditions of pressure and temperature at the depth from which the lava and ashes came, presumably 30^{km}.

Professor E. RUTHERFORD, in the Philosophical Magazine for August, 1906, has an article on the "Retardation of the α-particle from Radium in passing through Matter." "The photographic effect of the α-particles toward the end of their path in air decreases far more rapidly than the kinetic energy of the α-particles themselves. It is possible to determine with accuracy the value $\frac{mV}{e}$ for the α-particles emitted by radium, radium A, and radium F by measurements of the retardation of the α-particles of the single product radium C in passing through matter. Such a result affords an almost certain proof that the value of e/m is the same for the α-particles expelled from each of these products." The same author discusses the intensity of radiation from radioactive sources, and contrasts the photographic effect of radium emanations through apertures of various forms with the radiation of the sun. In the case of the latter, Lambert's law of cosines applies; that is, the intensity of radiation from any point varies as the cosine of the angle between the normal and the direction of the emitted light. This law does not apply to a thin layer of radio-active substance. Hence we find great inequalities in the distribution of the photographic effects. A number of photographs accompany the paper (Phil. Mag., August, 1906).

The September number of the same journal contains an article by M. LEVIN, "On the Origin of the β-rays emitted by Thorium and Actinium." M. Levin has been working with Professor Rutherford. It was found that actinium by itself is a rayless substance. A remarkable similarity was found to exist between the modes of transformation of thorium and actinium. The same journal contains a paper "On the Radioactive Matter in the Earth and the Atmosphere," by A. S. EVE, communicated by Professor Rutherford. The author believes that emanation exists in the atmosphere, but thinks that more experimental work must be done before any exact value can be assigned to the number of ions produced.

"About $1{\cdot}8\times10^{-11}$ grams of radium bromide is the estimated equivalent of the active matter per c.c. present in the earth's crust sufficient to account for the penetrating radiation. This appears to be about four times as large as the average amount found by Strutt by direct observation of rock specimens. The ionization of the atmosphere is due partly to penetrating radiation from the active matter in the earth, partly to α-radiation from the emanation in the atmosphere." J. T.

8. *Velocity of X-Rays.* — E. MARX describes minutely his investigation of this velocity. The method depends primarily upon the property which the X-rays possess of ionization of a gas. Electric waves were produced along parallel wires according to Lecher's system. The velocity of these waves was assumed to be the same as the velocity of light. A Röntgen tube was, therefore, so connected with the Lecher system, that the differences of potential due to the presence of nodes or ventral seg-

ments of the electrical waves, influenced the emanation of the X-rays. The rays from such a X-ray tube proceeding through an aluminium window struck an electrode contained in a Faraday cylinder; this electrode was connected with an electrometer. Changes in wave length were produced by moving a bridge on the two wires of the Lecher system. The X-ray tube was moved to and fro until maximum effects of ionization were produced in the receiving tube. These efforts produced corresponding deflections of the electrometer. The relation of the doubled displacement of the bridge in the Lecher system to the displacement of the X-ray tube gave the ratio of the velocity of light to the velocity of the X-rays. The ratios differ only one-half per cent from the value of light.—*Ann. der Physik*, No. 9, 1906, pp. 677–722. J. T.

9. *Formation of Ozone from Oxygen and Atmospheric Air by Silent Discharges of Electricity.*—E. WARBURG and G. LEITHÄUSER state that silent discharges between small spheres are necessary for the formation of ozone from atmospheric air. A number of tables are given of the output, in the case of spheres, charged in one case positively and in another case negatively. The results are plotted and appear in the form of straight lines.—*Ann. der Physik*, No. 9, 1906, pp. 734–742. J. T.

10. *Oxidization of Nitrogen by Silent Discharges in Atmospheric Air.*—E. WARBURG and G. LEITHÄUSER show that:

(1) Nitrose gases in the presence of ozone are easily absorbed by dilute soda lye.

(2) With silent brush discharges from the positive terminal sphere in atmospheric air, at the room temperature, independently of the moisture of the air, 10 liters of NO is oxidized by an ampere hour.

(3) The oxidized quantity of nitrogen mixture increases with increasing temperature and then decreases with the formation of the ozone.

(4) A quantity of N_2O_4, indicating 1^{cc} NO in 1500^{cc} lessens the formation of ozone when the silent discharge occurs in atmospheric air.—*Ann. der Physik*, No. 9, 1906, pp. 743–750. J. T.

11. *Influence of Moisture and Temperature on the Ozonizing of Oxygen and of Atmospheric Air.*—E. WARBURG and G. LEITHÄUSER show that with a silent discharge, moisture effects the ozonization more in the case of air than with oxygen, and that a rise of temperature to 80° and constant pressure, produces little effect in the case of both oxygen and atmospheric air.—*Ann. der Physik*, No. 9, 1906, pp. 751–758. J. T.

II. Geology and Mineralogy.

1. *The Tenth International Geological Congress at Mexico City.*—The Congress began its sessions on Thursday, September 6, 1906, and adjourned on Friday, the 14th of the same month. Previous to the opening meeting excursions were made, as follows: To the south for eight days to view the Archean and Tertiary in the narrow canyon of the Tomellin on the way to Oaxaca, the Lower Cretaceous in the mountains west of Tehuacan, and the ancient ruins at Mitla. To the west for twelve days, two excursions were given,—one to Jorullo to see the volcanoes Toluca and Jorullo, and the other to the only active volcano in Mexico, Colima, and the geysers. The best attended excursion before the Congress was the one to the east for three days, to see the deeply eroded Cretaceous at the edge of the high mesas down which the railroads descend to the dissected Miocene level, and then to the present ocean level at Vera Cruz. On the way back to Mexico City a stop of a few hours was made at Orizaba to view the symmetrical volcano of the same name and the nearly vertical strata of the Middle Cretaceous. The most extensive and varied excursion was the one for three weeks immediately after the meetings of the Congress, to the north as far as El Paso and east to Tampico. On alternate days, during the sessions of the Congress, excursions were given to Cuernavaca, to San Juan Teotihuacan to examine the work of restoring the great pyramids of the Sun and Moon, and to the Pachuca silver mines. These excursions were of great profit to all, while the hospitality received en route was lavish.

The opening session of the Congress was held on the morning of September 6, at eleven o'clock, in the Salon de Actos of the School of Mines, in the presence of the President of Mexico, his cabinet, his personal and official staff, and the ministers of foreign countries. A short opening address was given by Sr. Luis Salazer, Director of the School of Mines. The address of welcome was read by the Subsecretary of Fomento and the Honorary President of the Congress, Sr. Andrês Aldasoro. The retiring President of the Congress, Prof. Emilio Tietze, made a very pleasing address, and was followed by the President-elect, Sr. Josê G. Aguilera, Director of the National Geological Institute of Mexico. The Secretary-elect, Sr. E. Ordóñez, outlined the work of the sessions. The President of the Republic then pronounced the Congress opened. The succeeding meetings were held in the Geological Institute, a building just completed and containing accommodations for the excellent equipment, collections, library, and staff of the Mexican Geological Survey.

The following are the officers of the present Congress, who either in 1909 or 1910 will turn over the machinery of the Tenth Congress to the Eleventh, to be held at Stockholm:

President, Sr. José G. Aguilera.
Secretary General, Sr. E. Ordóñez.

Vice Presidents: Austria, C. Diener; Germany, H. Credner, A. Rothpletz, and F. Frech; France, A. Offret; Great Britain, T. Anderson; Norway, E. Brögger; Sweden, H. Sjögren; Russia, Th. Tschernyschew; Roumania, G. Stefanescu; Italy, V. Sabatini; Spain, C. R. Arango; Hungary, von Szadeczky and B. de Inkey; Canada, F. D. Adams and A. P. Low; United States, T. C. Chamberlin, C. W. Hayes, S. F. Emmons, and A. Heilprin; Philippine Islands, M. D. McCaskey; Mexico, E. Böse; Cuba, S. de la Huerta; Venezuela, E. Urdaneta; Australia, T. W. E. David; Japan, T. Iki.

The members actually participating in the Congress numbered 292. Of these 130 were from Mexico, from America 58, Manila 1, Canada 8, Honduras 1, Cuba 2, Germany 44, Austria 6, France 11, England 4, Belgium 3, Russia 3, Finland 2, Italy 2, Sweden 1, Roumania 3, Bohemia 1, Australia 1, and 1 from Japan. In other words, Europe was represented by 80 members, and the Americas by 207. At this Congress, however, the percentage of non-geologists was probably greater than usual, and of ladies there were 27.

The Russian Spendiaroff prize was awarded to Tschernyschew in recognition of his great work entitled "Die obercarbonischen Brachiopoden des Ural und des Timan."

Through the death of von Zittel the Paleontologia Universalis lost its President, and to this vacancy the Council of the Congress elected Prof. Frech of Breslau. To the American Committee was added R. Ruedemann, the other members being C. D. Walcott, H. S. Williams, and Charles Schuchert. Canada is represented by J. F. Whiteaves and Mexico by E. Böse and C. Burckhardt.

A large geological map of North America, including Greenland, was distributed to the members. It is the joint work of the National Surveys of Canada, United States, and Mexico, and was printed by the U. S. Geological Survey for the Congress. It is understood that this map will undergo further revision and will also eventually appear as one of the Professional Papers of the U. S. Geological Survey. It will supply a great lack in American geology.

In the main, the following are the titles of papers read by their authors at this Congress:

F. D. Adams: Explanation of the Geological map of North America, distributed to the members of the Congress.

T. Anderson: On the principal results of the Swedish Antarctic expedition. Read by H. Sjögren.

H. F. Bain: Some relations of paleogeography to ore depositions in the Mississippi Valley.

C. Burckhardt: Sur l'existence dans le Jurassique supérieur mexicain d'Ammonites et Aucelles.

A. P. Coleman: Interglacial periods of Canada.

N. H. Darton: Geologic classification in the north-central portion of the United States.

T. W. E. DAVID: On the morphology and evolution of the Australian continent, and particularly in regard to the Cambrian and Permo-Carboniferous glacial climates.

H. L. FAIRCHILD: Pleistocene of western New York.

F. FRECH: Ueber die Klimaänderungen der geologischen Vergangenheit. Ueber Aviculiden von paleozoischen Habitus aus der Trias von Zacatecas.

A. HEILPRIN: The concurrence and interrelation of volcanic and seismic phenomena. On the Martinique eruptions.

E. O. HOVEY: La Sierra Madre Occidentale de l'État de Chihuahua.

B. DE INKEY: Sur la relation entre l'état propylitique (Grünstein) des andésites et la genèse des filons liés à cette roche.

K. KEILHACK: On the onyx deposits at Etla in the State of Oaxaca.

J. F. KEMP: Ore deposits at the contacts of intrusive rocks and limestones.

J. KÖNIGSBERGER: Ueber den Verlauf der Geoisothermen in Bergen und seine Beeinflussung durch Schichtstellung, Wasserläufe und chemische Processe.

L. DE LAMOTHE: Le climat de l'Afrique du Nord pendant les Périodes Pliocène et Pleistocène.

A. C. LAWSON: The earthquake of San Francisco, California. On the Quaternary history of California.

W. LINDGREN: On ore deposition.

M. MANSON: The causes of the glacial epoch.

W. G. MILLER: The Pre-Cambrian rocks of Central Canada.

K. RENZ: Ueber das ältere Mesozoicum Griechenlands.

V. SABATINI: Sur la dernière eruption du Vésuve.

G. STEFANESCU: Description du squelette d'un nouveau genre de Dinotherium gigantissimum.

J. D. VILLARELLO: Sur le remplissage de quelques gîtes métallifères.

W. H. WEED: Origin and classification of ore deposits.

C. S.

2. *A Descriptive Catalogue of the Tertiary Vertebrata of the Fayûm, Egypt*, based on the collection of the Egyptian Government in the Geological Museum, Cairo, and on the collection in the British Museum (Natural History), London; by CHARLES WILLIAM ANDREWS, D.Sc. 4to. Pp. xxxviii, 324 with 25 plates and 48 text-figures. London, 1906 (published by order of the Trustees of the British Museum).—This fine quarto volume gives not alone a full descriptive catalogue of the collections in the Cairo Museum and in the British Museum (Natural History) which were made in the Fayûm; but a general discussion of the physiography and geology of the region and of the characters and relationships of the remarkable forms which ancient Egypt, ever the land of wonders, has brought to light. Mr. H. J. L. Beadnell, the maker of the Cairo collection, has given a very full account of the topography and geology of the Fayûm province in Egypt and upon his detailed report the sketch contained in the catalogue is based.

The Fayûm is situated west of the Nile valley in a latitude some 57 miles south of Cairo. The region is a roughly circular depression the lower part of which is occupied by a large brackish-water lake, the Birket-el-qurun, about 25 by 6 miles in extent. During Pleistocene times this lake was of vastly greater area, the deposits of the former waters being rich in vertebrate and molluscan remains. Numerous stumps of trees in one or two places

indicate that formerly portions of the surrounding country were wooded. Along the northern side of the lake nearly the whole of the vertebrate remains have been gathered from beds of middle and upper Eocene age. Of these vertebrates all classes except the Amphibia have been found, though bird fragments are referable to one species only. By far the most abundant are the Mammalia, which are followed in numbers by the reptiles.

The Mammalia are divided into three sections; (1) the land mammals which seem to be truly endemic to the Ethiopian region; (2) forms of which close allies occur in other regions in approximately contemporary deposits; and (3) the aquatic mammals. It seems probable that some of the last are also of endemic origin, having arisen from native land mammals.

Of the first series, curiously enough, all are ungulates of the less specialized orders. The most notable of these is Arsinoitherium, a most bizarre creature of elephantine proportions and massiveness, and which bore upon the snout two great upward and forwardly projecting horn cores, while above the orbits were two more though of much smaller dimensions. Andrews, while expressing doubt as to the relationships of Arsinoitherium, thinks that it may have originated from the same stock that gave rise to the Hyracoidea. The latter are quite abundant in the Fayûm, but remains throw little or no light upon the history of the group.

The light thrown upon the past history of the Proboscidians is the feature of the greatest scientific interest because of the extreme deficiency of our previous knowledge of the order, as none were known older than the Miocene before the Fayûm forms came to light. Osborn, among others, had pointed out the probability that Africa would be found to be the original home of the Proboscidea, the Hyracoidea, and several other families, believing that a succession of migrations from Africa to Europe occurred, notably at the end of the Eocene, at the beginning of the Miocene and again in the earliest Pliocene. It was in the early Miocene migration that the elephants passed out of Africa for the first time. The earliest known proboscidian is Mœritherium, which occurs first in the Quaer-el-Sagha (middle Eocene) beds and persists until the upper Eocene. This creature suggests the tapir in size and general appearance, and while the dental formula is almost complete, many elephantine characters are foreshadowed in the skull. The next proboscidian genus is Palæomastodon, of which some of the smaller species are evidently intermediate between Mœritherium and the later elephants. The larger Palæomastodons were about the size of a half-grown Indian elephant and were elephant-like in appearance except for the elongated symphysis of the lower jaw, which was prolonged beyond the skull and was covered only by the fleshy snout. The neck was still somewhat long and the creature could reach the ground with its lower incisors and with the probably prehensile muzzle. The further evolution of the group is shown in Tetrabelodon from the

European lower Miocene, a creature similar in size and appearance to the Indian elephant except that the trunk was inflexible because of its being supported by the more elongated symphysis. In Mastodon however the symphysis shortens, leaving the trunk free; at the same time vestiges of the elongated condition of the jaw occur in some mastodons and in the peculiar sharp process of the symphysis of modern elephants.

The Fayûm researches have also thrown light upon the probable community of origin of the Sirenia, the Proboscidea and the Hyracoidae.

The Creodonts are also present of the family Hyænodontidæ and the development of the Zeuglodonts from a creodont ancestry is shown. The zeuglodonts of the Fayûm, taken together with a species, *Procetus atavus*, from the near-by Mokattan Hills, form a series showing a complete transition so far as the teeth are concerned from the Creodonts to the Zeuglodonts.

The bird remains seem to be that of a true Ratite and suggest the Ethiopian region as a point of origin of some at least of the main sub-divisions of the Ratitæ.

The Reptilia are represented by crocodiles, turtles, and snakes. There are no Amphibia and the fishes are either Elasmobranchs or Siluroids and of no great interest.

The summary points to the great importance of Africa as a center of mammalian evolution, not alone of modern true mammals, but of their Theriodont ancestors. This being the case, not only the Tertiary, but the Mesozoic deposits of this region may be expected to throw much light upon the history of the Mammalia. The Dark Continent seems to be a veritable land of promise to the vertebrate paleontologist. R. S. L.

3. *Geology of the Owl Creek Mountains with Notes on Resources of Adjoining Regions in the Ceded Portion of the Shoshone Indian Reservation, Wyoming;* by N. H. Darton. *United States Geological Survey. Senate Document No. 219, 59th Congress, 1st Session.* Pp. 48, with 11 plates and 1 text figure. Washington, 1906.—This paper, of the general form of the bulletins of the U. S. Geological Survey, is published as a Senate document in response to a request from the Senate for such information relating to the geology and natural resources of that portion of the Shoshone Reservation which was to be opened for settlement in July, 1906, as was in the possession of the U. S. Geological Survey. The report has a geological map on the scale of 4 miles to the inch, and many attractive photographic illustrations. J. B.

4. *The Copper Deposits of the Robinson Mining District, Nevada*; by Andrew C. Lawson. *Univ. of Cal. Publications, Bull. of the Department of Geology*, vol. iv, No. 14, pp. 287–357. May, 1906.—This bulletin gives a good account of the geology of the Egan Range, one of the larger members of the Basin Range system of mountains traversing eastern Nevada. The Archean basement is not exposed, the rocks ranging in age from the Cam-

brian to the Carboniferous and holding in places intrusive masses of granitic and monzonitic rocks. Intrusive porphyries and extrusive rhyolites are also present. Considerable space is devoted to the contact phenomena and their relations to the ores. J. B.

5. *The Montana Lobe of the Keewatin Ice Sheet;* by FRED. H. H. CALHOUN. Professional Paper No. 50, U. S. Geol. Surv., 1906. Pp. 62, with 7 plates and 31 figures.—This report covers a region of much interest to glacialists, an area which lay between the Keewatin ice sheet and the mountain glaciers coming from the west. In studying this region four important subjects were considered—the eastern drift, the mountain drift, the deposits on the intervening area (which was not glaciated), and the relations of these three surface formations to one another. It was found that for thirty miles back from the margin the average slope of the glacier must have been about 50 feet per mile. It is further stated that this ice sheet also undoubtedly turned the Missouri from a northern course and made it tributary to the Mississippi River. J. B.

6. *Les Lac Alpins Suisses. Étude Chimique et Physique;* par le Dr. FÉLIX-ERNEST BOURCART. Pp. 130, with plates and 22 figures. Genève, Georg & Co., Editeurs, 1906.—This work, to which was awarded a prize by the Helvetian Society of Natural Sciences, was undertaken at the suggestion of Professor Duparc as a subject for a thesis. Thirty-three lakes were examined in detail and complete observations made upon the color of the water, transparency, the temperature at the surface and at maximum depth and other features. Chemical analyses were also made of the waters and the results are finally tabulated. The report thus brings together a valuable body of data. J. B.

7. *The Species of Botryocrinus;* by F. A. BATHER. Ottawa Nat., vol. xx, pp. 93–104, August 15, 1906.—This paper contains a comparison of all previously described species, with fresh diagnoses based on the dorsal cups. The species are: Swedish, *B. ramosissimus* Ang., *B. cucurbitaceus* (Ang.): British, *B. ramosus* Bather, *B. decadactylus* Bather ex Salter MS., *B. pinnulatus* Bather, *B. quinquelobus* Bather; Australian, *B. longibrachiatus* Chapman; N. American, *B. nucleus* (Hall), *B. polyxo* (Hall), *B. crassus* (Whiteaves), *B. americanus* Rowley. All these are Silurian except the two last, which are Devonian and approach the Carboniferous *Barycrinus* in shape. American workers are invited to consider the relations of *Botryocrinus* to *Cosmocrinus*, *Barycrinus*, and *Vasocrinus*. [Author's abstract.]

8. *Soils, their Formation, Properties, Composition and Relations to Climate and Plant Growth in the Humid and Arid Regions;* by E. W. HILGARD. Pp. xxvii, 593, with 89 figures. —Every student of soils will welcome this volume from one of the oldest and ablest soil investigators in North America. The book is unique because of the full comparison between soils of humid and arid regions and its special emphasis upon the physics

and chemistry of arid soils, a natural result of the author's long experience in the arid west. The book is further characterized by its strong treatment of the effect of soil character upon native vegetation, for the value of which the author has been contending for half a century. The fundamental question of classification as involving the relative value of physical and chemical properties in plant production and as a convenient means of reference to cultural values, is discussed in a thoroughly convincing manner. In view of the recent discussions on the relation of soil texture and chemical constitution to the composition of the soil-water, Hilgard's conclusions are of the highest interest and value, and strongly contravene the assertion that natural solutions of water-soluble soil ingredients are essentially of the same composition in all soils. A commendable feature of the soil analyses is their statement in terms which insure application. They really constitute a sort of restatement of refined analyses such as give the conclusions an immediate and practical value to the agriculturist. I. B.

9. *Brief Notices of some recently described Minerals.*— KLEINITE is an oxychloride of mercury described by A. Sachs from Terlingua, Texas, and named after Prof. Carl Klein of Berlin. It occurs in slender hexagonal crystals of a sulphur-yellow to orange color; hardness 3–4; specific gravity = 7·441. The composition deduced is $H_4Cl_2O_2$. Sachs regards this mineral as identical with one noted by Moses ("No. 5," this Journal, xvi, 263) and also with that announced by Hillebrand (Ibid., xxi, 85). —*Sitzungsber. Akad. Berlin*, Dec. 21, 1905; *Centrbl. Min.*, 200, 1906.

BELLITE is a chromo-arsenate of lead from the Magnet Silver mine, Magnet, Tasmania; it is named after Mr. W. R. Bell by W. F. Petterd. It occurs in delicate tufts and velvety coatings lining cavities in a soft iron-manganese-gossan; minute hexagonal crystals are sometimes visible. The color is bright crimson to orange-yellow; hardness 2·5; specific gravity 5·5. An analysis by J. D. Millen gave:

As_2O_3	CrO_3	PbO	P_2O_5	V_2O_5	Al_2O_3	SO_3	Cl	SiO_2	
6·55	22·61	61·68	0·04	0·11	0·01	0·05	0·52	7·59	= 99·16

GIORGIOSITE is a name given by Lacroix to a basic hydrated magnesium carbonate forming a white powder with sodium chloride and other salts at the fumaroles of Santorin at the eruption of 1866. The powder consists of minute radiated spherules. This is inferred to be identical in composition with a salt described by Fritzsche having the formula $4MgCO_3.Mg(OH)_2.4H_2O$. Another associated substance in white flocculent masses is probably hydromagnesite.—*Bull. Soc. Min.*, xxviii, 198.

SILICOMAGNESIOFLUORITE, as its name expresses, is essentially a fluosilicate of magnesium. It is described by P. Zemiattschenski from Lupikko, Finland. It occurs in crystalline aggregates of half-spherical or spherical forms with radiated and fibrous

structure. The color is ash-gray or light greenish and bluish with satin luster; hardness 2·5; specific gravity 2·91. The empirical formula deduced is $H_2Ca_4Mg_2Si_2O_7F_{10}$, which may be written $5RF_2.2RSiO_3.H_2O$.—*Zeitschr. Kryst.*, xlii, 209.

STILPNOCHLORAN is an alteration-product of thuringite described by Kretschmer from the iron mines of Gobitschau near Sternberg, Moravia. It forms aggregations of small cleavable scales, sometimes irregularly grouped, also radiated or fan-shaped. The color is yellow to bronze-red; hardness 2 to 3; specific gravity 1·82. An analysis gave:

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	H_2O	P_2O_5	
33·30	4·37	44·33	0·34	1·22	1·73	14·10	0·37	= 99·76

The formula calculated is $H_{24}(Ca, Mg)(Al, Fe)_{10}Si_9O_{46}$.—*Centralbl. Min.*, p. 203, 1905.

MORAVITE is a chloritic mineral closely resembling thuringite, also described by Kretschmer from a locality near Gobitschau (see above). An analysis gave:

SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O,Na_2O	H_2O	C	P_2O_5	
49·30	22·71	5·04	13·99	*tr.*	1·82	1·10	4·95	0·55	*tr.*	= 99·46

The formula deduced is $H_4(Fe, Mg)_3(Al, Fe)_4Si_7O_{24}$.—*Centralbl. Min.*, p. 293, 1906.

PARAVIVIANITE is a variety of vivianite containing small amounts of manganese (2·01 p. c. MnO) and magnesia (1·92 MgO), described by S. Popoff from the limonite deposits of the Peninsula Kertsch.

The same author has given the name KERTSCHENITE to a hydrated basic iron phosphate from the same region. This occurs in dark green to black crystalline aggregates with a hardness of 3·5 and specific gravity of 2·65. The mean of two analyses gave:

P_2O_5	Fe_2O_3	FeO	MnO	MgO	CaO	H_2O	
28·20	32·93	9·49	1·92	1·55	0·47	24·98	= 99·54

The calculated formula is (Fe, Mn, Mg) $Fe_2P_2O_{10}.7H_2O$.—*Centralbl. Min.*, p. 112, 1906.

OTAVITE is a new cadmium mineral described by O. Schneider from Otavi in German Southwest Africa. It occurs in crystalline crusts with upper and lower surfaces covered with minute rhombohedrons. The color is white to reddish and the luster brilliant adamantine. Qualitative tests lead to the conclusion that it is a basic carbonate of cadmium. The same locality yields azurite, malachite, cerussite, linarite, etc., also greenockite as a yellow powder on malachite.—*Centralbl. Min.*, p. 388, 1906.

CHLORMANGANOKALITE is a name provisionally given by H. J. Johnston-Lavis to a double chloride of manganese and potassium occurring in canary-yellow rhombohedral crystals in cavities in ejected masses found on the flanks of Vesuvius after the eruption of last April. *Nature*, lxxiv, 103. Associated with this are fine cubes of a potassium-sodium chloride corresponding to 6KCl. NaCl, which the same author calls CHLORNATROKALITE.

DOUGHTYITE, described by W. P. Headden, is a hydrated basic sulphate of aluminium occurring as a white precipitate in connection with some of the Doughty Springs in Delta County, Colorado. The composition of the air-dried material is given by the formula: $Al_2(SO_4)_3.5Al_2(OH)_6.21H_2O$. — *Proc. Colo. Sci. Soc.*, viii, 66.

III. ASTRONOMY.

1. *Parallax Investigation of 162 Stars, Mainly of Large Proper Motion.* Transactions of the Astronomical Observatory of Yale University: Volume II, Part I, pp. 207, Folio. Published by FREDERICK L. CHASE, MASON F. SMITH and WM. L. ELKIN.—The results of Dr. Elkin's work with the Repsold Heliometer on the parallax of 10 first magnitude stars of the northern heavens were published in 1902, as Part VI of vol. I of these Transactions. It may be noted here that nine of these stars have a reliable parallax, varying from 0·02″ to 0·33″, and it is somewhat significant that two of the three of inconsiderable parallax have also inappreciable proper motion, while the seven remaining have noticeably large proper motion, varying from 0·20″ to 2·29″, while the average parallax of 0·11″ represents a distance of 29 light-years.

During the progress of this work, which together with the triangulation of the Pleiades and that of the Group in Coma Berenicis by Dr. Chase had demonstrated the capacity both of these observers and their instrument for the highest order of parallax work, plans were formed for an investigation of all the stars of known large proper motion across the line of vision convenient for observation (designated rather loosely in the report as "all the rapid moving stars"). This work has developed in the course of its prosecution so far beyond the limits anticipated that it has occupied the larger part of the time of Dr. Chase for 13 years, Dr. Elkin having been interrupted by ill health and largely occupied by work in meteorite photography. It has also enlisted the services of Mr. M. F. Smith since 1901.

By 1895 about 100 stars had been measured at two epochs of greatest parallax effect, the original design being to detect parallax without attempting the fullest determination of its magnitude, but the discussion of these measurements promised such valuable results that it was decided to both enlarge and intensify the work by including more stars and extending the measurements over four periods, the last two being taken in reverse order, as well to eliminate more completely the effect of proper motion as to guard against the effect of systematic error which might possibly be considerable in a limited number of observations.

The precautions taken against systematic errors, whether resulting from habits of observation, direction of comparison stars or difference in their color or brightness, as well as from

imperfections in the micrometer screw or progressive change in its scale value, must impress the reader as original, judicious and comprehensive; and as the value of the parallax work depends chiefly on the completeness of these eliminations, the inferences drawn by the authors as to the sigificance of their results may be accepted with great confidence because of the high order of this part of the work.

An interesting example of the thoroughness of the investigation of sources of systematic error is the discussion by Dr. Chase of the effect of difference of color between the parallax star and its star of comparison. It is assumed that the light of a red star being refracted less than that of a white comparison star, the angular distance between them will be affected.

The treatment of this topic is of such intrinsic interest and so typical of the thoroughness of the whole investigation of sources of systematic error that it seems well to reprint it here entire from the text of the report—the tables of measurements, occupying many pages, being omitted.

"*Observations of red stars for color effect.*—The work of the preceding pages, in which every precaution to eliminate known sources of error was employed, appears to us to be free from all systematic error, except perhaps one due to the star's color. Any perceptible difference in the mean refrangibility of the light of two stars might possibly produce an effect upon the measured distance between them which would be a function of the hour angle, and hence affect their apparent relative parallax, since it is generally impossible for practical reasons with our instrument to make observations at the two different parallax epochs otherwise than on opposite sides of the meridian. To ascertain whether an error due to this cause is appreciable in actual observation, Dr. Chase, in 1898 and 1899, made a series of observations on five highly colored stars selected from Krüger's *Catalog der Farbigen Sterne*, carrying out the investigation in the following manner:

The plan was at the epoch when the star culminates about midnight to measure the distances between the red star and each of two nearly equally distant comparison stars, one preceding and the other following, and as nearly as possible on the same parallel of declination, at rather large hour angles both east and west of the meridian. By taking two comparison stars we were able, as in the parallax work, to correct for any change in the scale value, and to eliminate any errors varying with the time.

The refraction of two stars with light of a different mean refrangibility being represented by

$$\beta \tan z, \text{ and } (\beta+\Delta\beta) \tan z$$

the measured distance between two such stars should receive, besides the correction for differential refraction, the additional correction

$$\Delta\beta \tan z \cos (p-q)$$

where z denotes the zenith distance, p the position angle of the red star from the comparison star, q the parallactic angle, and $\Delta\beta$ the supposed color effect.

The following pages give the measures corrected for refraction and aberration, the value of $\tan z \cos(p-q)$ for each observed distance, and the sums, differences, corrections for temporary scale value, and corrected differences, as in the series for parallax determination. These last, by their variation from an assumed mean difference, furnish the equations of condition which follow, in which x and x' represent the required corrections to the assumed mean difference for each epoch, $\Delta\beta$ the quantity to be determined, whose coefficient is the difference of the values of $\tan z \cos(p-q)$ for the two distances, and the second member the observed difference for each night minus the assumed mean difference. The star Krüger 1181 was specially selected because it had a close neighboring star presumably of average color, and as a test of the value of the method this latter also was observed with respect to the same comparison stars in conjunction with the red star and symmetrically with it, so that the conditions should be absolutely the same. For both stars, likewise, the treatment and solution were carried out in precisely the same manner. . . . . .

If we arrange the results of the previous pages in the order of the stars' redness as given by Krüger, we have—

Krüger	985	Color 6·0	$\Delta\beta = -0{\cdot}019''$	$\pm$ 0·019″	Wt. 63·6
	1080	7·0	$+0{\cdot}005$	$\pm$ 0·020	64·4
	1078	7·1	$+0{\cdot}009$	$\pm$ 0·015	16·0
	1181	7·8	$+0{\cdot}014$	$\pm$ 0·018	55·7
	1108	8·7	$+0{\cdot}046$	$\pm$ 0·017	45·2
W. B. 15^h,	745	--	$-0{\cdot}003$	$\pm$ 0·021	55·6

An inspection of these results would seem to indicate that there is a discernible color effect conforming with theory, the mean light of the red star being apparently refracted less than that of the comparison stars, except in the case of Krüger 985, although the amount is very small except for very red stars. This conclusion is corroborated by a comparison of the results for Krüger 1181 and W. B. 15^h, 745, investigated under exactly the same conditions. The result for the latter coming out so nearly zero is a most satisfactory confirmation of the accuracy of the work. That the color effect is not greater rather tends to confirm Sir David Gill's opinion that the heliometer observer's tendency is to bring the similarly colored parts of the stars' spectra rather than the brightest parts into coincidence.

Now what influence this possible source of error, if real, may have upon our parallax results can be easily shown. Scarcely any of the measures were made at a zenith distance greater than 60° and the average was about 50°. The following table gives the value of the factor $\tan z \cos(p-q)$ for each twenty degrees of declination at 50° zenith distance, assuming p, the position angle of the red star from the comparison star to be 90°, for which

value the difference of the factors for east and west observations is found to be a maximum. And taking the average double parallax factor to be 3·50 the last column gives the extreme correction that would have to be applied to the parallax, in which for $\Delta\beta$ is to be taken its value for a star of the same degree of redness.

Decl.	q	$\tan z \cos(p-q)$		$\frac{E-W}{3\cdot50}\Delta\beta$
		East	West	
0°	30·3°	−0·59	+0·59	−0·34 $\Delta\beta$
+20	52·3	−0·94	+0·94	−0·54
+40	65·0	−1·08	+1·08	−0·62
+60	74·4	−1·14	+1·14	−0·65
+80	77·5	−1·15	+1·15	−0·66

Thus considering that the color effect for a most highly colored star is not likely to be greater than $0\cdot66 \times 0\cdot046'' = 0\cdot03''$ we feel justified in concluding that any vitiation in our parallax results, due to this cause, is presumably well within their probable error."

Appreciating the rigorous methods employed in the work we can accept with confidence the inferences drawn by the authors from the analysis of the parallaxes obtained.

These are best summarized by again quoting from the text:

"The present investigation furnishing, as it seems to us, a homogeneous series of parallax values, we have thought it of interest to make a number of classifications of the results independent of the material hitherto obtained by other observers. While we cannot claim any very great precision for the individual results, determined as these are from such a comparatively limited number of observations, yet we do attach considerable weight to the mean values of the various groups we have formed, and consider these values of unquestionable significance.

These classifications are comprised in the five following tables. Table I gives an arrangement in order of the size of the proper-motion of the star under consideration; Table II, a similar one in order of the star's magnitude; Table III, in order of the size of the parallax; Table IV, in order of Right-Ascension, subdivided into two classes north and south of Declinations +30°, and finally Table V, according to the spectral type and classes as given in the Draper Catalogue."

Of the results shown in these tables the following are the most interesting:

Table I reveals, as might be expected, a distinct interdependence of parallax and proper motion, especially in the group with proper motions exceeding 1″. The data of Table II point to a small but undoubted relation between parallax and magnitude. Table III emphasizes the connection between proper-motion and parallax, none of the negative parallaxes corresponding to proper-motions greater than 1″, and a marked progression being very apparent.

Table V does not conform to the law deduced by Kapetyn of connection between parallax and types of spectra, but the data are hardly sufficient to disprove the law.

The parallaxes grouped in order of magnitude appear as follows :

Number of stars with negative	parallax,	−0·13″ to −0·00″	36
small	"	+0·00 to +0·02	40
considerable	"	+0·04 to +0·09	49
large	"	+0·10 to +0·20	38

Of the last group the average magnitude is 5·8 and the average parallax 0·163″, corresponding to a distance of 20 light-years, which is two-thirds that of the 9 first magnitude stars. The average proper motion of the group is 0·90″, one and one-half times that of the first magnitude stars.

Two results of more popular interest may be stated as follows : Proper motion is a far more reliable guide than brightness in estimating distance.

There is probably not more than one star in the northern heavens nearer to us than 61 Cygni.

In the last group is found the noteworthy addition to our knowledge of astronomy furnished by this work. All of its stars will be subjects of study in the observatories of the world for many years. W. B.

2. *Publications of the United States Naval Observatory*, Superintendent, Rear-Admiral Asa Walker, U. S. N. Second Series, 4to, Volume IV, in four Parts, Parts I to III.—Part I contains Transit-Circle Observations of Sun, Moon, Planets and Miscellaneous Stars, 1900–1903. Part II contains Transit Circle Observation of Sun, Moon, Planets and Comets, 1866–1891. Part III contains Transit Circle Observation of Standard and Zodiacal Stars, 1901–1902.

Part IV forms a separate volume and is largely devoted to a discussion of observations made at the total solar eclipses of May 28, 1900, and May 17, 1901, with numerous illustrations. At the former, stations were occupied on the central line at Barnesville and Griffin, Georgia, and at Pinehurst, N. C. For the eclipse of 1901 an expedition was sent to Sumatra under the charge of Prof. A. N. Skinner and several stations occupied at which successful observations were made yielding important results, especially as regards the form of the corona. This subject is illustrated by a series of excellent plates.

IV. Miscellaneous Scientific Intelligence.

1. *A Text-Book in General Zoology*; by Henry R. Linville and Henry A. Kelly. Pp. x+462, with 233 illustrations. New York, 1906 (Ginn & Company).—This is an elementary text-book designed particularly for secondary schools. It contains, however, a vast amount of matter of interest to the general reader and in this respect differs widely from most books of the kind. The pupil or reader will here find the dry bones of anatomy and classification clothed with interesting accounts of habits, life history, relationship, and evolution, while the bearing of each fact on the general principles of biology is indicated. The book is to be accompanied by a pamphlet of suggestions for laboratory work. With a suitable laboratory course and judicious selection of topics the study of this book should arouse in the mind of the young student a love of nature and an eagerness to make the personal acquaintance of the animals considered, although many elementary courses are conducted in such a way as to secure an exactly opposite result. A large part of the illustrations are original and are unusually attractive. W. R. C.

2. *Illustrations of British Blood-sucking Flies with notes;* by Ernest Edward Austen. Pp. 74; 34 plates. London, 1906 (Printed by order of the Trustees of the British Museum).—This work consists of reproductions of colored drawings prepared for exhibition in the British Museum, with interesting comments in popular language on each of the species illustrated. The 34 plates are well printed by the three-color process and represent the insects many times natural size, with few exceptions each figure occupying the whole of a large octavo plate. They might, therefore, be used to advantage to accompany the actual specimens in museums other than the one for which their originals were intended. This is particularly the case because many of the species are of very wide distribution, occurring not only in Great Britain, but also throughout Europe, Asia, and North America, and some in Africa and Australia. W. R. C.

3. *A Synonymic Catalogue of Homoptera. Part I. Cicadidæ;* by W. L. Distant. Pp. 207. London, 1906. (Printed by order of the Trustees of the British Museum. Sold by Longmans & Co., etc.)—This first part of the British Museum Catalogue of Homoptera is devoted to Cicadidæ, and is prepared by Mr. W. L. Distant, who has given particular attention to this family of the Rhynchota. The fact that there has been no catalogue of the family published recently gives especial value to this exhaustive work.

Obituary.

Dr. Ludwig Boltzmann, Professor at the University of Vienna and eminent for his contributions to theoretical physics, died by his own hand in September last at the age of sixty-two years.

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The new edition of *H. Rosenbusch text-book* (by H. Rosenbusch and E. A. Wülfing), Vol. I, "Mikroskopische Physiographie der Mineralien," has just come out in two parts, each of which contains a considerable number of photographic reproductions showing the microscopical features and structures of the rock-forming minerals. By the kindness of the author and publisher we have been able to prepare *lantern slides of the original photos*, which we now offer in two sets of 72 slides each; collection A, representing the figures on the plates IV–XV of part I; collection B, those of the plates I–XII of part II.

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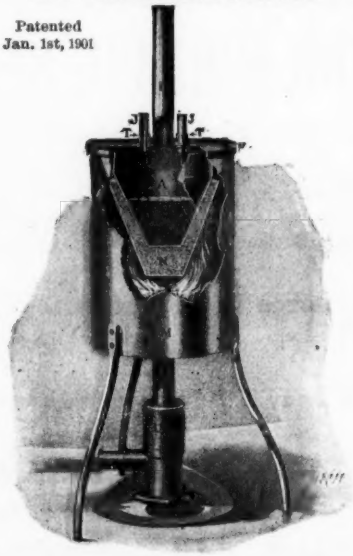

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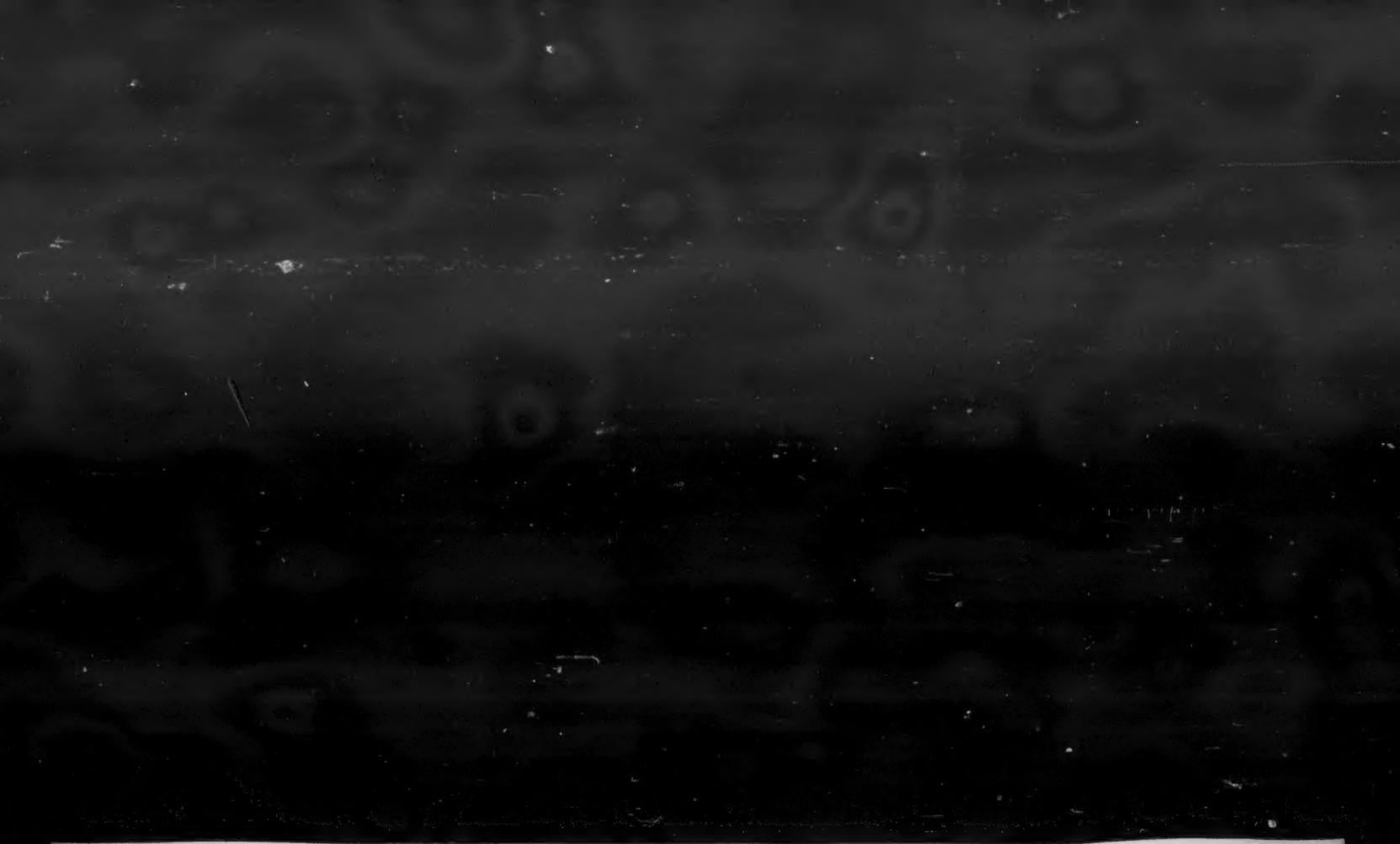
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